THE SOIL SCIENCE SOCIETY OF FLORIDA

PROCEEDINGS
VOLUME XII
1952

Twelfth Annual Meeting of the Society
Citrus Experiment Station
Lake Alfred
December 12 and 13, 1952

OFFICERS OF THE SOCIETY
1953

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Retiring Officers listed on page 168.

ACKNOWLEDGMENTS

The Executive Committee of the Society wishes to take this opportunity to extend to Dr. A. F. Camp and his Associates at the Citrus Experiment Station its very best thanks, in behalf of members and guests who attended the meetings of December 12 and 13 at the Station; for the welcome accorded was most generous and complete and the facilities placed at the disposal of the Society were perfect in every respect for the purpose.

Likewise it is desired to express our sincere gratitude to Dr. R. M. Salter, Chief, Soil Conservation Service, U.S.D.A., for interrupting a very heavy schedule of work to be with us. His evening lecture on the outlook for the Soil Survey program in the future was of paramount interest to all phases of Agricultural planning or any other planning in Florida, that has anything whatsoever to do with the land. Coming as it did right at the time State and Federal programs in this field were being reviewed and revamped it was of course especially timely.

The tours of inspection of the Citrus Station building and grounds which covered nutrition plots, packing plant and facilities, processing and by-products plant, laboratories and shops were especially appreciated by those members and guests who were visiting the Station for the first time.

The ultimate in hospitality was revealed, however, in the wonderful chicken barbecue that was served on the grounds of the Experiment Station on Friday evening and the luncheon at noon Saturday. Arrangements for these occasions were made by President Wander and his Associates. We are grateful not merely for the wonderful food and excellent opportunity for visiting with friends and distant co-workers, new and old but also for the very definite expedition they lent to the progress of the meetings on Friday evening and on Saturday afternoon.

Air view of Citrus Experiment Station at Lake Alfred from the East. At left—Experimental Packing House; at rear—Shops, Laboratories, Greenhouse and Storage; right (in central block) the old Experiment Station Building and—center—the Central Laboratory and Administration Building in the Auditorium of which the meetings of the Society were held.

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DEDICATION

DR. ROBERT M. SALTER

Born in 1892, at Huntington, Indiana, Robert M. Salter moved at an early age to Ohio where he attended the public schools and Ohio State University. He majored in agronomy and was accorded a Master's Degree in agricultural chemistry. He later received an Honorary Doctor of Science Degree from Rutgers University.

His first post in the field of science was as Instructor of Agricultural chemistry at Ohio State University, 1914-1915. He went to the West Virginia Agricultural Experiment Station in 1915 to become Assistant Soil Chemist, then Soil Chemist and Professor of Soils, and, 1919, Agronomist and Professor of Agronomy.

In 1921 Dr. Salter returned to Ohio State University to take charge of the agronomy extension program. He became Chief of Agronomy, Ohio Agricultural Experiment Station in 1925; Chairman of the Department of Agronomy, Ohio State University, in 1929; and Associate Director of the Ohio Agricultural Experiment Station in 1940. While in Ohio, Dr. Salter directed all the soils research in that state. This included cooperation in the establishment of the first erosion experiment station in the United States and the initial soil conservation demonstrations.

Dr. Salter left Ohio in 1940 to become Director of the North Carolina Agricultural Experiment Station, but the next year he was called to Washington, D. C., to become Chief of the Division of Soil and Fertilizer Investigation, Bureau of Plant Industry, U. S. Department of Agriculture. In 1942 he was appointed Chief of the Bureau of Plant Industry, Soils, and Agricultural Engineering and held this post until 1951 when he became Chief of the Soil Conservation Service.

As an agronomist and soil scientist, Dr. Salter's attention has centered largely on soil management. For many years he was Chairman of the National Joint Committee on Fertilizer Application. Particularly outstanding has been Dr. Salter's work in the use of combinations of limestone, manure, fertilizers and crop rotations for building up soil productivity to sustain high crop yields. Dr. Salter is a Fellow of the American Society of Agronomy. He was President of this Society in 1936. He is also a Fellow in the American Association for the Advancement of Science. Dr. Salter has traveled widely throughout the United States, and in Central and South America. He has contributed for many years to scientific journals, bulletins, and farm papers.

DR. ROBERT M. SALTER

THE SURVEY OF AMERICA'S SOIL RESOURCES

Robert M. Salter *

I am glad for this opportunity to talk to the Soil Science Society of Florida about the survey of our soil resources. If you share my opinion that the subject is a bit too technical for an after dinner speech, I trust that you will place the blame upon your errudite chairman, Dr. Allison, and not me.

Not so many years ago, few people besides soil scientists themselves were concerned about this subject. But today we find a growing and understanding interest in soils and what they mean among farmers, businessmen, educators and others.

This is a healthy development, because productive soil is essential to all of us. Just as we cannot live without air or water, neither has man yet devised any adequate substitute for the soil in producing the major part of his food and many other essentials to his very existence.

Soil likewise is the basis of most of the Nation's and the world's wealth. Truly, the skyscrapers of Wall Street rest on the productive soils of America.

Although soil spreads continuously over most of the earth's land surfaces, it is really made up of many individuals. These individual soils vary one from another just as one kind of plant differs from other plants or one kind of animal from other animals. Even in a single state such as Florida there are several hundred different soils. It is not uncommon to find six or ten different soils on a single farm. In the United States several thousand individual soils have been identified.

Each kind of soil usually occurs in a number of separate areas. Each area has an upper boundary which coincides with the surface of the land. Each has a lower boundary at the depth to which living forces are effective. Each has an outer boundary where it joins other soil types. Areas of individual soils commonly form a mosaic or patchwork. Each kind of soil can be defined by describing a typical profile, the deviations from that typical profile, and other features such as slope and stoniness.

A profile, as you all know, is a vertical section down through the soil to a depth of several feet consisting of layers, one below the other.

The nature or arrangement of these layers, or horizons in the language of the soil scientists, are important to root penetration, to moisture storage in the soil, and to the amounts and availability of plant nutrients — to illustrate some ways in which they affect plant growth. Moreover, the nature and arrangement of the horizons reflect the past history of the soil.

Soils differ from one another in varying degrees. Some are as closely related as are the different species of pine trees, whereas others are no more alike than are a pine tree and a corn plant.

If we think of Florida and forget the rest of the nation for a moment, we can at once see that there are wide ranges in the important characteristics of soil types. Soils in the Everglades are flat, naturally wet, black

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* Chief, Soil Conservation Service, U. S. Department of Agriculture, Washington, D. C.

in color, neutral to alkaline, and consist mostly of organic matter. Not many miles away are the Lakeland and Blanton soils of the central ridge where so much of the citrus fruit is grown. These soils are rolling, excessively drained, low in organic matter, pale yellow to white in color, low in moisture holding capacity and very low in their natural contents of plant nutrients.

To emphasize the range we might add the Leon soils of the flatwoods section and the Greenville soils of northwest Florida. The Leon soils are flat, wet, dominantly light colored, sandy, strongly acid and naturally low in fertility. The Greenville soils, on the other hand, are dark red in color, well drained and rolling, have good moisture holding capacities, are rather high in clay, and relatively fertile. This illustrates the wide ranges in important properties of soils within one State.

The ranges become much wider when we consider the country as a whole. We may then go from the red and yellow leached soils of the cotton belt naturally low in fertility but with large potentialities for production under modern scientific management to the black soils of the spring wheat region in the northern Great Plains, some of the naturally most fertile soils in the world. This range can be enlarged further if we include the soils formed under evergreen forests in Maine and those formed under desert shrub vegetation in Arizona.

The kind of soil at any place depends upon its history, especially its natural history. The amount of rain that falls each year, the hours of sunshine, the kinds of plants that grow there, the slope of the land are all important to the kind of soil in any given place. Scientists have long recognized five principal factors in soil formation: these are climate, living organisms, topography, parent rock, and time. Each soil under natural conditions is a result of a particular combination of these five factors. Each possesses a particular combination of characteristics.

Each kind of soil has a certain range in its use capabilities. These are narrow for some soils and wide for others. The capabilities of soils for use differ both locally and regionally. Within a single quare mile here in Florida there are soils suitable for citrus production, for improved pasture or for forest and there are also soils which are adapted only for forest or range pasture. This kind of distinction becomes more striking when the soils of northwest Florida are compared with those of northeast Montana. In the latter region the choice must be made between spring grain and pasture, whereas the list of possible crops in northwest Florida would fill half a page.

Along with their differences in use capabilities, soils are also unlike in management requirements. That hardly needs mention here in Florida, although I do think it worthwhile to emphasize the fact. The tillage, fertilizer, and water control practices following in the growing of vegetables on Okeechobee muck south of the lake are much different from the fertilization, irrigation and other elements of management in the growing of oranges on Lakeland fine sand in Polk County. These in turn differ much from methods used to establish and maintain improved pastures on Leon sand in Brevard County. If we shift our attention from Florida to the whole of the country, the ranges in management requirements for the thousands of soils becomes even greater.

When we use soils we change them. We clear the forest or plow the prairie. We drain the wet soils and irrigate the dry ones. We tend

to lower fertility levels in the rich soils and raise it in the poor ones. We have allowed soils to erode and wash away, with formation of spectacular gullies in some places.

One example of a gradual but nonetheless striking change which follows from our use of soils in the gradual subsidence of peat and muck in the Everglades as cultivation continues. Slowly but surely the surface of the soil is being lowered by the decay of organic matter encouraged by tillage. By and large, we tend to reduce or eliminate the natural differences among soils as we continue to use them for the production of crops, pasture or forest.

Our main interest in soils rests on their capacity to produce plants we need for food, fiber, and shelter. As the population of our country grows, we shall need larger and larger amounts of food and fiber. Production of those essentials must come from our soils, largely the ones we are now using.

Long-time high levels of agricultural production are therefore necessary for the general welfare of our nation. The welfare of all of the population is thereby linked, whether directly or indirectly, to the use and management of our soil resources. Wise use and management is essential, and to that end we must know our soil resources as fully as we can.

In our agricultural research and through the experiences of farmers we have devolped a great store of information on how to use different soils. This store of information is still growing. But we cannot repeat these experiments on every field. Some way of extending information on the management requirements of a soil from the site of the experiments to the farm fields where it may apply is needed. The purpose of soil classification is to provide a sound basis for this transfer of information about soils.

This transfer of information from one state to another is most efficient when there is a nation-wide system for defining and classifying soils. Another advantage of national coordination of this work rests in the use of soil maps to provide nation-wide inventories of soil resources.

Population estimates for 1975 indicate expanded needs for the products of our soils. Will we be able to meet these needs? What production techniques are going to be most effective in different parts of the country in obtaining increased production? Where can we look for potentially responsive soils, where the application of research findings can create new production in the way you are doing here in Florida? The answers to these and similar questions will depend on a national inventory of our soil resources, made in such a way that soils of various parts of the country can be compared, and their similarities and differences established.

Nation-wide systems of soil classification are also needed in order to guide public investment in land development and reclamation activities. Will we get the most for our money from developing new irrigated lands in the arid sections or from clearing and improving some of our southeastern land that is now unproductive or marginal? The answer to this question lies in a large part in accurate predictions of how the soils of the areas in question will produce after the proposed development. Such predictions as these are made through comparison of the soils of the areas in question with those of other places where similar developments have been tried. These comparisons are best made when the soils of the

different parts of the country are mapped, described, and classified according to a standard system.

Soil classification has many other uses in addition to its use as a tool in applying research findings to farms. The highway engineers are using soil types as a basis for cataloging their information on engineering properties and subgrade characteristics of soils. They frequently find soil maps to be very useful in predicting the engineering problems of new highway construction.

The county assessor of Polk County, Iowa, has just finished a revaluation of the rural lands in his county, based on a recent soil survey. Here, the soil scientists supplied a map showing the distribution of different soils on each farm, and in cooperation with specialists in Agricultural Economics they gave a relative rating to each soil. This rating was based on the predicted production under the agriculture of the county. The assessor then worked out his valutions, which included consideration of location values and improvements.

The first organized mapping of soils in the United States began in four widely scattered areas in 1899. Three 2-man parties comprised the field force which mapped areas in Maryland, Connecticut, Utah, and New Mexico that summer. From that modest beginning a continuing program has provided maps for approximately 1600 areas during the past 53 years. In the first surveys, attention was given to the possible uses of soils and also to their productivity for various crops. Early in the course of the work it was recognized that surveys were being made to classify and correlate soils, determine their distribution and extent and learn their adaptations for crops.

Careful study of the classification and mapping of soils from 1899 to the present time shows that the work clearly reflects the state of knowledge in the soil science of its day. The classification of soils at any given time can only be as good as what is known about them. Over the years the classification and mapping of soils has slowly changed as the knowledge of soils and their behavior has grown.

A major part of the results of the national soil surveys has appeared in the series of soil survey reports published by the U. S. Department of Agriculture. All of you are familiar with the series which was started at the turn of the present century. Approximately 1600 soil surveys have been published over the past 52 years with the majority of them being at least 25 years old. Many of the reports therefore summarize what was known about the soils of an area prior to 1930.

Changes in the form and content of soil survey publications have accompanied the changes in classification and mapping. Some of the present-day maps are 3 to 8 times as large for the same unit area as were the maps of 25 years ago. Common scales for publication are now 2″ per mile with a few maps being issued at smaller scales and a fair number at larger scales. The general scale of soil maps 25 years ago was 1″ per mile.

Modern soil maps carry up to 16 times as many miles of soil boundaries as did those of yesteryear. Moreover, the reports nowadays provide far more specific information on the use capabilities, management requirements and probable crop yields for the individual soil types and phases. Approximately one million square miles in the United States have been covered by soil surveys of various kinds during the past 53 years. Of that

total, at least ⅓, and probably nearer ½, consist of older surveys which have only limited usefulness in meeting modern agricultural needs.

The rate of progress during recent years has been approximately 5½ million acres annually, with roughly ¾ of this total comprising detailed soil surveys and the remaining ¼ reconnaissance surveys of various kinds.

One of the first techniques to be used by the Soil Conservation Service in its job of getting conservation on the land was the use of a soil map as a basis for planning the soil conservation program on each farm. As the work progressed, the soundness of this decision to use soil maps as one of our principal tools has been demonstrated again and again. It seems very likely that the technique of basing farm plans upon a soil map may prove to be one of the important constributions of the Service to American agriculture.

Inasmuch as soil maps are such a vital link in our program for applying technology to farms, a soil mapping organization was developed within the Service. This has provided for the most effective coordination of mapping and planning activities.

As the work progressed and became nation-wide in scope, it became evident that some grouping of soils according to their capabilities for use and their needs for conservation practices would help in coordination of the work. The use-capability classificaiton was developed to meet this need.

This classification is a grouping, for a specific purpose, of the various units delineated on the soil maps. Eight classes are used, with Class I representing soils that can be cultivated intensively, with little or no danger of erosion or other permanent deterioration. Classes II, III, and IV can be cultivated, but hazards requiring special practices for the prevention of permanent deterioration increase in severity from Class II to IV. Classes V, VI, and VII are not suited for cultivation, but may be used for pastures or forest production. The difficulties encountered in using land in these classes for pasture or forestry increase in severity from Class V to VII. Class VIII represents lands limited in their use to wildlife habitats or recreational areas.

Within all these classes except Class I, subclasses are established according to the nature of the most important characteristic limiting use intensity. Thus soils hazarded by erosion are placed in the "e" subclass, and soils with a water control problem in the "w" subclass of the appropriate class. For example, several soils suited for cropping but having drainage difficulties of increasing severity would fall into subclasses IIw, IIIw, and IVw as the drainage difficulties became more critical.

The grouping used in our technical guides and farm plans for fitting information in soil management, conservation practices, and treatment needs to specific soils is called the capability unit. Capability units are a division of the subclass. Within the capability unit are grouped soils having similar problems, crop adaptability, management requirements, and conservation needs. Productivity should be relatively uniform within a capability unit. The management groups used in some of the published soil surveys are in general very similar to the capability units.

These capability units are coming to be our most important grouping in using soil science on farms, and the subclasses and classes are now used primarily in estimating conservation needs and appraising the conservation problems of broad areas.

While various groupings of soils are proving useful, each for specific purposes, many of the farm planners of the SCS, as well as others using soil surveys, work with the individual soil units as delineated on the maps, without grouping. This is particularly true of those with considerable experience in the area where they are working, or those in areas where the soil pattern is relatively simple. This way of using the maps permits the use of the most specific information available about the soils of the area.

The soil mapping program of the SCS since its beginning has covered about 410,000,000 acres. At the present time we are mapping about 37,000,000 acres per year.

Careful examination of the progress map of SCS surveys and those recently completed by the BPISAE shows some overlap. In most of these counties the same map has provided the basis for SCS farm plans and for the published basic Soil Survey. This in itself suggests the need for close coordination of this work.

Last winter we undertook a field study of mapping and the use of maps, looking toward technical coordination of the mapping work of the two agencies. This study was carried out by staff members from the SCS and the BPISAE, and extended over a 6-month period. One of the conclusions reached in this study was that the map requirements for a good job of conservation farm planning and those for a scientific soil survey were pretty much the same.

In the development of arrangements for achieving a high degree of technical coordination of the two mapping agencies, it became evident that one agency combining all soil survey activities would be desirable. Inasmuch as the soil maps are such an important working tool in the Soil Conservation Service, the administration of this combined program was placed in the SCS by the Secretary.

In this new Soil Survey organization we hope to preserve the best features of both of the mapping programs entering into the combination. In the SCS there has been developed a great deal of experience and skill in using soil maps as a basis for a technical assistance program. This experience indicates the need for very close cooperation between the soil scientists engaged in mapping and the farm and ranch planners.

Our ideas of the map requirements of a sound technical assistance program have been developed through wide experience. The use-capability concept has proved highly useful. In the basic Soil Survey, a great deal of progress in standardization of terms for describing and defining soils has been made in the last decade.

Fundamental studies of soil genesis, classification, and correlation have led to a better understanding of the properties and distribution of different soils and to more efficient and accurate mapping. The series and type classification has been improved through these studies and is the common basis for reporting research results by State experiment stations.

In the new organization these fundamental studies leading to improvement of the nation-wide system of classification will be continued and expanded. Then, too, as research workers develop new ways of using and managing soils, a system of yield estimates or productivity ratings becomes more valuable as a way of helping farmers make their choice of alternative ways of using their land. We feel that attention to this phase

of soil survey interpretation will help us work with farm management economists in developing sound plans for farms and ranches.

Close cooperation with State college workers in all phases of the program will be maintained and strengthened. We look forward to working out more rapid and effective programs for the reproduction and distribution of survey field sheets and the publication of county maps and reports.

As the program progresses we plan to make maps from which practically all users can get the information they need. The field sheets and mapping legend will be designed so that, either by direct use or by interpretation, a map suitable for farm planning in soil conservation districts, for use in the research and educational programs of the State colleges, for planning the soils phases of programs, such as TVA, the Bureau of Reclamation, and highway construction, and for published basic Soil Survey maps can be obtained. In many of the current surveys this has already been accomplished, with resultant increases in the efficiency of all programs.

The procedures for mapping will be fitted to the needs of the agriculture of the area. For example, on an area where a new irrigation development is under consideration, the maps will need to be very detailed and show many features of the soil and underlying material, whereas in areas where forestry or range represent the only possible uses less detailed maps will meet the needs.

At times, generalized maps of certain areas may be prepared at a fairly rapid rate in order to guide broad programs for land development, with more detailed mapping within the area coming along as the program moves ahead. This has been a useful technique here in Florida in connection with some of your drainage activities.

An organization to carry out the USDA share of the responsibility in the field of soil surveys is being worked out. Based upon past experience and recognizing the future needs for the work, we have several basic principles to guide us.

First, the Soil Survey staff must have close working relationships with those who are using the maps in technical assistance and educational programs on one hand, and with research workers in all phases of soil science on the other. One of the most important responsibilities of the Survey program will continue to be to supply planning technicians in soil conservation districts with the maps needed as a basis for sound farm and ranch plans. Only through close working relationships with the planners and with research workers in soil management can the Soil Survey provide the kind of maps needed for application of the whole field of soil science to our operations program.

Second, we must provide for technical coordination at all levels in order to maintain a nation-wide system for the definition and classification of soils. Without this, the survey program cannot reach its maximum effectiveness as a way of transferring experience from one area to another, and as a scientific inventory of national soil resources.

Third, we must included within the Soil Survey the research activities needed to insure a continually improving program — one that will keep pace with the needs of a rapidly changing and progressively more scientific agriculture.

Fourth, close cooperation with the land-grant colleges and with other Federal agencies must be a part of the day-to-day operation of the program.

We believe that an organization and staff consistent with these requirements is possible. Naturally, the details of the arrangement will vary in different regions and States in order to fit the conditions of each area. Furthermore, we must look forward to making the changes that future developments indicate to be desirable.

In all of our consideration of this Soil Survey problem, we must keep in mind that the Soil Survey is not the end in itself. Soil Surveys are primarily a tool for helping us reach a further goal. This goal is to provide American farmers with the information they need to develop efficient, sustained systems of production that will meet the needs of the country for food fiber.

In order to reach the high levels of production likely to be needed in the years to come, American farmers should not have to choose between production and conservation. If the full weight of science is directed toward the problems of using and managing soils, farmers can achieve the needed production and still protect and improve their soil resources. Soil survey maps will be one of our most important aids in bringing this knowledge to bear upon each farm, and in helping each farmer choose from the developments of research, the way of managing the soils on his farm that is best fitted to his personal resources and objectives.

THE CHEMISTRY OF METAL CHELATES AND THEIR APPLICATION IN AGRICULTURE

IVAN STEWART AND C. D. LEONARD *

The word "chelate" comes from the Greek meaning claw and refers to the ring configuration when a metal ion combines with two or more electron donors. This reaction may be compared to two claws removing metal ions from solution. A simple metal complex, such as the ferrocyanide ion, is not a chelate and may be formed when a metal ion combines with a single electron donor. Simple complexes and chelates are formed by nearly all metals. There are large numbers of chelating agents but the electron donors which bind to the metals are limited to nitrogen, oxygen and sulfur. Metals can combine directly with carbon but the properties of the resultant organometal compounds are different from those of chelates.

In order to carry on agricultural research with chelates it is essential to understand certain of their properties. Werner (1) in 1891 noted a phenomenon by which apparently stable, saturated molecules combine to give molecular complexes. This is contrasted to valence bonds where molecules or atoms combine with unsaturated groups. Werner found that certain metal ions combined with a definite maximum number of other atoms to form a complex. This number is called the coordination number. The coordination number for Zn^{++} and Cu^{++} is 4, and for Fe^{+++} is 6. Some metals have a coordination number of 2 and others of 8 but metals with coordination numbers of 4 and 6 tend to form the most stable chelates. The coordination number of a metal may be used as a guide to determine the maximum number of groups of a complexing agent that will be bound to a single metal ion.

Morgan (2), who first used the term "chelate", discovered that when cyclic compounds are formed with a metal, linkage between the metal and the organic compound may occur in two or more places, the number depending upon the properties of the chelating agent. This worker used the terms bidentate, tridentate, and quadridentate, etc., meaning literally two-toothed, three-toothed, and four-toothed, etc., to designate the number of linkages. A metal with a coordination number of four, zinc for example, will bind two bidentate molecules, whereas a metal with a coordination number of six, like iron, is capable of holding three bidentate groups or two tridentate groups.

The chelation reaction proceeds according to the law of mass action. The concentration of the constitutents in the following reaction at equilibrium:

$$\text{Metal Ion} + \text{Chelating Agent} \rightleftharpoons \text{Metal Chelate}$$

are related by the mathematical equation

$$K = \frac{\text{(Metal Chelate)}}{\text{(Free Metal Ion)} \times \text{(Chelating Agent)}} \text{; where ( )}$$

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Florida Agricultural Experiment Station Journal Series, No. 138.

indicates the molar concentration. K is the equilibrium constant of the reaction and defines the molar ratio of the metal which occurs in the chelate to the metal in the ionized state. Where K is very large the metal *ion* concentration is very small. The K value is commonly referred to as the stability constant of the chelate and will vary depending on the metal, chelating agent and other factors.

Stability constants are useful guides that can be used to predict certain properties of chelates. The following is a list of stability constants of metal-ethylenediamine tetraacetic acid (EDTA) chelates (1) expressed as the logarithm of the K value:

	Log. K
Mg^{++}	8.69
Ca^{++}	10.59
Mn^{++}	13.4
Fe^{++}	14.45
Co^{++}	16.10
Zn^{++}	16.
Cu^{++}	18.3
Fe^{+++}	25.1

The higher the log K value the more stable is the complex and the lesser the tendency for the complex to yield metal ions. In general, this order of stability constants is followed by all chelating agents of the amino carboxylic type such as EDTA. From the above values it can be calculated that if a relatively small amount of EDTA is added to a solution containing the various metal ions, 10 million times more Fe^{+++} will be chelated than Cu^{++} and one billion times more Fe^{+++} than Zn^{++}. Likewise if Zn EDTA is added to a solution containing Fe^{+++} the iron will rapidly replace zinc in the chelate. This would seem to indicate that zinc chelates would not be effective in the presence of oxidized iron. This assumption does not take into account that iron and zinc have different properties that can be used advantageously. For example, in a mixture of zinc and iron, if the pH were raised to the point where all of the iron is precipitated, then the zinc would be chelated. Phosphates will form more stable complexes with iron than with zinc. By taking advantage of these properties in addition to selecting chelating agents that have approximately the same stability constants for zinc and iron, it is believed that some fairly useful zinc chelates can be found.

Chelation is like a great many other discoveries in that many years often elapse between the original discovery and its application. The first use made of chelating agents was in analytical chemistry. One of the earliest chelating agents to be used was 8-hydroxyquinolate. This reagent is used to chelate heavy metals in acid solutions and alkaline earth metals in solutions above neutral. The ideal condition would be to have specific chelating agents for each metal. Although specific chelating agents may occur in enzymes of organisms, probably the nearest approach to this in synthetic chemistry is the specificity of nickel for dimethyl glyoxime.

One of the most recent chelating agents to come into general use is ethylenediamine tetraacetic acid (EDTA). The properties of this compound make it useful for controlling metal ion concentrations. For example, if it is desirable to remove calcium from solution, a soluable oxalate

can be added and the metal precipitated. However, if first EDTA is added and then the oxalate, the calcium remains in solution. Following chelation this element ceases to exhibit any of its ionic properties. If the solution is submitted to electrolysis the chelated calcium will move to the anode instead of the cathode.

The properties of EDTA vary with pH: for example, at pH's above 6 the OH^- ion will compete with EDTA for Fe^{+++} until, at about pH 8, EDTA ceases to be a very effective chelating agent of this metal. On the other end of the pH scale the chelate becomes ionized in acid solutions to the extent that practically none of the metal will be complexed. Generally, iron and copper are chelated in acid solution, while Ca and Mg are chelated in alkaline solutions. EDTA will remove iron from ferric phosphate; however, since chelation is controlled by the law of mass action, there is in reality competition between PO_4, and EDTA for iron. Hence, if the PO_4 concentration is high enough with respect to EDTA, some iron phosphate will precipitate in spite of the presence of EDTA.

Work was started at the Florida Citrus Experiment Station more than a year ago on the use of chelates as sources of iron for trees (3). Previous to this time iron chelated with citrate, tartrate and EDTA had been used successfully in solution cultures. Iron EDTA, however, is the only source of this element that has been found to be readily available to trees growing in the field. Twenty grams of iron chelated with EDTA has consistently given good results in greening chlorotic trees growing on acid soils. Chemical analysis on the leaves of treated and untreated trees show that the iron content is increased from a low range of 25-40 ppm. up to 85-125 ppm. by the treatments. Increasing the rate of application above 20 grams of chelated iron has not consistently given higher iron content in the leaves. Additional chemical analysis of leaves from treated and untreated trees showed that the Mn, K, Ca, Mg, and N contents did not vary significantly with rate of application of chelated iron. Iron EDTA has not been found very effective on calcareous soils.

The Na Fe EDTA is highly soluble in water. This material was applied to field plots at the rate of 50 pounds per acre and soil samples were collected from the plots immediately following the application. Water-soluble iron was determined in the samples immediately and in the same samples 5 months later, after having been cultured at room temperatures. The amount of water-soluble iron in the samples was the same in both cases. This indicated that the EDTA had not undergone microbial decomposition during the five-month incubation period. However, in the field it was not possible to detect the Fe EDTA one month after the application. During this time 2 inches of rain fell and it was concluded that the iron leached below 12 inches — the depth to which the soil samples were taken.

In accordance with the known chemical properties of EDTA, a series of laboratory tests was made to determine its compatibility with various fertilizers. When Fe EDTA was mixed with dolomite for 24 hours 49% of the iron was fixed; under similar conditions rock phosphate fixed 41% of the iron, while phosphatic sand fixed only 3% of the iron. Studies are being carried out on iron fixation by various soils. Table 1 gives some of the results obtained. This information suggests that the calcareous soils on the East Coast contain factors independent of pH that fix the iron supplied in EDTA. The chemical procedures used are now in the process

of being varified with radio isotopes. The method of studying iron fixation used here may be useful in evaluating various chelating agents for calcareous soils.

Iron deficiency has been reported in plants in almost every state, as well as in South and Central America, the Caribbean area, Europe, the British Isles, and the Middle East. When a satisfactory solution can be found for this problem on all soils it should contribute materially toward increasing the world food supply.

TABLE 1.—Percent of Iron Added in EDTA Fixed by Soils in 24 Hours.

	pH	Fe Fixed Percent
1. Virgin Soil	5.3	0.0
2. Virgin Soil, 500 lbs. per acre $CaCO_3$ added	6.9	0.0
3. Virgin Soil, 4,000 lbs. per acre $CaCO_3$ added	8.0	2.0
4. Grove soil that has been receiving 18% P_2O_5 fertilizer	6.4	0.0
5. Grove soil that has been receiving 0% P_2O_5 fertilizer	6.3	2.0
6. East Coast Soil Fe def. area Ft. Pierce	7.9	53.0
7. East Coast Soil Green area	6.1	6.0
8. East Coast Soil Fe def. area Merritt Island	7.2	25.0
9. East Coast Soil Fe def. area Organic matter removed	11.3	92.5
10. East Coast Soil Green area Merritt Island	7.3	9.0
11. East Coast Soil Green area Organic matter removed	11.3	92.5
12. Muck	4.8	0.0

LITERATURE CITED

1. Martell, Arthur E., and Melvin Calvin. 1952. Chemistry of the metal chelate compounds. Prentice-Hall, Inc., New York.
2. Morgan, G. T., and H. D. K. Drew. 1920. J. Chem. Soc. 117, 1456.
3. Stewart, Ivan and C. D. Leonard. 1952. Chelates as sources of iron for plants growing in the field. Science 116: 564.

PRELMINARY REPORT ON CHELATED IRON FOR VEGETABLES AND ORNAMENTALS

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Iron chlorosis of vegetables and ornamentals has been a problem in old vegetable fields in the Sanford area for years. Various plants differ in their susceptibility to this disorder. For example, celery, the principal crop in this area, appears to be quite resistant, whereas corn is very susceptible. Gladiolus growers in this area have found from experience that a field which grows green corn will probably produce green gladiolus plants. Fields which produce a poor, yellow, stunted crop of corn will invariably do the same for gladiolus.

It has been reported that chlorotic gladioli will respond to weekly foliar sprays of ferrous sulfate; however, no correction was obtained when the iron salts were applied directly to the soil (11). Recent work (10) has added to the list of vegetables and ornamentals showing iron chlorosis which respond to iron sulfate sprays on the leaves, but not to soil applications of the same material.

Copper is recognized as an essential element for plant growth, but will cause chlorosis of numerous plants when present in excessive amounts in the soil. Copper has accumulated in old celery fields from years of copper sprays for disease control. For example, a comparison of the total copper in virgin and cultivated soil profiles of Leon fine sand shows 120 pounds per acre 24" for the virgin, and 1632 pounds per acre 24" for the cultivated, or an increase of 1512 pounds of copper (Cu) per acre 24" (10). Excessive copper has been implicated as at least one of the factors which can bring about iron chlorosis of plants in acid soils (3) (4) (5) (7) (8) (10).

Available iron has been maintained in nutrient solution by a single addition of ferric dipotassium ethylenediamine tetra acetate, using tomato, sunflower, corn, and barley as indicator plants (2). Stewart and Leonard have shown that iron chlorosis of citrus can be corrected by the addition of small amounts of chelated iron to the soil around iron chlorotic citrus trees (8) (9).

Definitions (1) (6) (12) of several chemical terms may be in order at this time. A *complexing agent* is any compound which will inactivate a metallic ion. A *chelating agent* is any compound which will inactivate a metalic ion with the formation of an inner ring structure in the molecule, the metallic ion becoming part of the ring. A *sequestering agent* is any complexing or chelating compound which forms a water soluble metal complex compound.

EXPERIMENTAL RESULTS

Ferric potassium ethylenediamine tetra acetate was prepared by dissolving ethylene diamine tetra-acetic acid (EDTA)[1] in KOH and adding ferrous

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[1] Trade names for EDTA are Sequestrene, manufactured by Alrose Chemical Company, Providence 1, Rhode Island, and Versene, manufactured by Bersworth Chemical Company, Framingham, Massachusetts. The corresponding trade names for Fe—EDTA are Sequestrene NAFe and Ferro-Grene.

sulfate as described by Jacobson (2). This Fe — K — EDTA when added to the soil around iron chlorotic corn plants in a Sanford field during February 1952 brought about a greening of the plants within one week, even though the soil (0—6") contained 683 p.p.m. of total copper (Cu). Chlorotic cabbage plants in old vegetable fields were likewise greened by adding this chelated iron to the soil.

A series of mature, iron chlorotic, gladiolus plants in the field were treated with from 5 to 25 grams of Fe — EDTA (12% Fe), a chelated iron compound, in the soil around the plants. Within a week the plant which had received 5 grams of the material was green, whereas 25 grams per plant had produced obvious injury, including firing of the leaves. The intermediate dosages produced increasing degrees of injury, beginning with 10 grams of Fe — EDTA per plant. Since then, gladioli on a field basis have been greened by the addition of one application of 20 pounds per acre of Fe — EDTA (12% Fe). Similar favorable results with gladioli have been obtained by the application of either 150, 300, or 450 pounds per acre of an intimate mix of Na_3 — EDTA (5.84% by weight), iron (0.78% Fe derived from iron sulfate), and 93.38% inert ingredients. One application of Fe — EDTA or intimate mix of Na_3 EDTA and ferrous sulfate to the soil before planting, or as a side dressing, has been sufficient to supply the iron required to overcome chlorosis up to and including harvest.

Hibiscus plants showing iron chlorosis have put out new green leaves within one week after either 5 grams of Fe — EDTA (12% Fe), or 50 grams of the intimate mix of Na_3 EDTA and iron (0.78% Fe) from iron sulfate, were applied to the soil. Similar response to chelated iron has been observed on chlorotic St. Augustine grass.

Chelated iron will green iron chlorotic plants either as a foliar spray or as a soil amendment. When used on the leaves, a water solution containing 0.5% by weight of ferrous sulfate greened iron chlorotic corn leaves without injury. However, a water solution containing 0.5% by weight of Fe — EDTA (12% Fe), although it greened the corn leaves, produced severe burning at this concentration. A lower concentration of Fe — EDTA might have greened the leaves without injury. Also, various crops may have different susceptibilities to injury from chelated iron. It will take time to work out the details for various crops. At the present time, where practical, soil applications of chelated iron look more promising than foliar sprays for the correction of known iron chlorosis.

Chlorotic Chinese cabbage and mustard greens on old celery land have been greened on a field scale by the application of 300 pounds per acre of a commercial mixture of Na_3 EDTA (5.84%) and iron (0.78% Fe) derived from iron sulfate. Favorable crop response to chelated iron in Florida has been reported[2] also for cucumbers, beans, okra, azaleas, hydrangeas, ixora, and grasses, including St. Augustine, Centipede, and Pangola.

Numerous other iron chlorotic vegetables and ornamentals, which to date have not responded to iron compounds applied to the soil, but have responded to foliar iron sprays, undoubtedly will react in time to chelated iron supplied through the roots. Experiments with replicated plots of

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[2] Personal communications.

celery receiving various sources of iron, including Fe — EDTA, are under observation at the present time.

SUMMARY

Various iron chlorotic vegetables in the field, including corn, cabbage, mustard greens, and Chinese cabbage, associated with excessive copper in the soil, have responded favorably to chelated iron (Fe — EDTA) applied to the soil, whereas ferrous sulfate alone was ineffective except as a foliar spray. Iron chlorotic ornamentals, including gladiolus and hibiscus, have responded in a similiar manner. Celery is still under observation.

LITERATURE CITED

1. Bersworth, Frederick C. Powerful organic complexing agents, the Versenes, for exacting chemical control of cation in solutions. Technical Bulletin No. 2. Bersworth Chemical Co., Framingham, Mass. Section I, p. 11. 1952.
2. Jacobson, L. Maintenance of iron supply in nutrient solution by a single addition of ferric potassium ethylenediamine tetra acetate. Plant Physiol. **26**: 411-413. 1951.
3. Reuther, W., and Smith, P. F. Effect of high copper concentration in sandy soil on the growth of citrus seedlings. Soil Science: (In press). 1953.
4. Reuther, W., and Smith, P. F. Iron chlorosis of Florida citrus groves in relation to certain soil constituents. Proc. Fla. State Hort. Soc. **65**: (In press). 1952.
5. Reuther, W., Smith, P. F., and Specht, A. W. Accumulation of the major bases and heavy metals in Florida citrus soils in relation to phosphate fertilization. Soil Science **73**: 5: 380. 1952.
6. Sequestrene: Ethylenediamine tetra acetic acid. Technical Bulletin, Alrose Chemical Co., Providence 1, Rhode Island. 1952.
7. Smith, P. F., and Specht, A. W. Heavy metal nutrition and iron chlorosis of citrus. Manuscript submitted to Botanical Gazette. 1952.
8. Stewart, I., and Leonard, C. D. Iron chlorosis—its possible causes and control. Citrus Magazine. June 1952.
9. Stewart, I., and Leonard, C. D. Chelates as source of iron for plants growing in the field. Science **116**: 3021 p. 564-566. 1952.
10. Westgate, P. J. Preliminary report on copper toxicity and iron chlorosis in old vegetable fields. Manuscript, Fla. State Hort. Soc. Proc. 1952.
11. Whitner, B. F., Jr. Fla. Agr. Exp. Sta. Ann. Report **1948**: p. 145.
12. Martell, A. E., and Calvin, M. Chemistry of the metal chelate compounds. Prentice-Hall, Inc., New York, N. Y. 1952.

SYMPOSIUM: THE RELATION OF TREATMENT AND MANAGEMENT TO THE CONTROL OF SOIL-BORNE DISEASES AND INSECTS—INCLUDING NEMATODES

THE SOIL IN ITS RELATIONSHIP TO PLANT NEMATODES

G. Steiner *

INTRODUCTION

It has been previously emphasized that numerically and dynamically nematodes are a most important part of the edaphon, the life association in the soil. They regularly make up a high percentage, frequently as much as 99%, of the soil metazoans. Since their mode of feeding and the nature of their food is very diverse and since otherwise many different even special phenomena of life occur in this group, their dynamic effect is manifold and significant. Our present discussion, however, will be restricted to only a segment of this nematode life in the soil,—that of plant nematodes.

The proper consideration of this segment of soil life is a necessity for the soil scientists and the practitioner working with soil. Unawareness of the plant nematode factor has invalidated extensive fertilizer tests, has led to misinterpretations not only of experimental results but also of actual field situations. Plant nematodes can greatly influence and modify the behavior of a soil in regard to crop production, to fertilizer response, and to growth of plants. Plant nematodes may simulate mineral deficiencies and lack of moisture. Root gall formations caused by nematodes have been incorrectly interpreted as bacterial nodules, not only by growers but also by investigators. Chlorotic discolorations that are not infrequently connected with heavy nematode attacks on roots of affected plants may disappear after application of a mineral corrective and for that reason have been wrongly interpreted as to their primary cause. Thus plant nematodes, if ignored, may be a cause of error in various ways for the researcher as well as the grower. Unfortunately the many aspects of the relationship of the soil to plant nematodes have been little studied. The proper approach would be that of a team of various specialists involved in these problems. At present the soil scientist blames the nematologist for not understanding the soils and, conversely, the nematologist is frequently horrified at the nematological concepts of the soil specialist. As a Society, it is to your credit to have recognized how unfortunate this situation is. To my knowledge you are the only soil science society ever to discuss nematological problems, and for this reason the opportunity to speak to you is greatly appreciated.

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THE SOIL PHASE OF PLANT NEMATODES

Not all plant nematodes have a soil phase.—at least not an obligate one. For example, the nematode (*Aphelenchoides cocophilus* Cobb) causing the red ring disease of the coconut palm is carried from palm to palm by a rhinoceros beetle without the intermediary of soil. Other plant nematodes have only a temporary soil phase, sometimes restricted to the egg stage and the preparasitic larva, in other instances including one or both adults. Still other forms remain continually in the soil and feed on underground parts of plants without entering them. Thus there are plant nematodes without a soil phase, others with a temporary, and still others with a permanent one. The last group is possibly the most numerous one. Since control of plant parasitic nematodes by therapeutics is still in its infancy, procedures for the elimination of these noxious forms from the soil are paramount. It is therefore the soil phase of these nematodes that usually offers most promise for control action.

PLANT NEMATODES ARE DESCENDANTS OF FREE-LIVING SOIL NEMATODES

As far as is known, plant parasitic nematodes are descendants of soil inhabiting nematodes, not of nematodes found parasitic in higher or lower animals. They are an ecological group, not a taxonomic unit. Present evidence indicates that the offsprings of many soil inhabiting nematode taxa have become either facultative or obligate parasites of plants. Both of the recognized main subdivisions of the phylum Nematoda, the Phasmidia as well as the Aphasmidia contain a large number of plant parasitic forms. Here, again, these parasitic forms do not belong to single taxonomic units of lower degree. There are a few nematode families of which all the known members are exclusively plant parasitic (e.g. Heteroderidae, Criconematidae), but various genera and families have some members living as plant parasites as well as free living soil inhibitants. There are also species that appear able to live free in the soil but also as parasites on or in plants.

SOIL FACTORS THAT AFFECT PLANT NEMATODES

One of the most common questions raised in connection with soil and plant nematodes concerns the depth of their penetration in the soil and the location of their maximal concentration. In other words what is the relationship of the soil profile to the occurrence of plant nematodes? The A horizon of course is that of the main concentration but the B horizon may also be penetrated wherever roots grow in it and organic material happens to be present. Even in the regolith plant nematodes may be found if roots occur there. Available food, temperature and moisture are the factors conditioning the distribution maxima, which accordingly may be near the surface or deeper.

The soil through its structural make-up offers plant nematodes the conditions for a cavernicolous life; such as, 1. pore space with moisture-saturated air, 2. a film of moisture over the crumbs of soil, 3. a narrow temperature amplitude slow in its movements, and 4. good protection from light and the lethal action of the rays of the sun. Thus a porous soil is particularly suitable for our nematodes; light sandy soils have long been known to favor plant nematodes and especially to promote their spread.

Heavy clay soils are not exclusive and preventive of plant nematode infestations but they have a restraining effect on their spread. A root-knot infected tomato plant e. g., if set out in field with clay soil may not contaminate a neighboring uninfected plant while such a contamination is certain in a light sandy soil.

The mineral and chemical nature of a soil appears of minor significance to plant nematodes except in cases of extreme aberrations, neither is the amount of organic matter except that a stage of advanced decay is a deterrent for them. Excessive amounts of humic acids appear also to repell plant nematodes. Experimental work on this whole subject however has not been performed.

Moisture is a crucial factor for conditioning the activities of plant nematodes in the soil. Proper moisture promotes nematode life; it particularly makes possible locomotion and migration. Drought, on the other hand is inimical to these nematodes. As a protection from drought some plant nematodes can enter a state of dormancy and be resuscitated upon the re-advent of moisture. This adaptation may climax in special phenomena such as that observed in some species of Ditylenchus, where hundreds of thousands of specimens may aggregate for dormancy and form curd-like masses. On the other hand excess of moisture in the form of water is detrimental to certain plant nematodes. For example, the flooding of land for prolonged periods of 3 or more months may remarkedly reduce root-knot nematode infestations.

Since nematodes in the soil actually live within a film of moisture that covers the soil particles the opinion has been expressed that they might be considered as freshwater forms. In entertaining such a conception the fact is overlooked that soil moisture is not water in the common sense, but a solution of salts and other compounds of a highly varied make-up and concentration. Any one attempting to culture the soil phase of plant nematodes should consider this fact. The use of plain water for culture purposes has often been unsuccessful because of the fact that water is not the equal of soil solution.

The soil offers plant nematodes a shelter against temperature extremes and sudden and rapid temperature changes. Plant nematodes with a permanent soil phase (e.g. *Xiphinema americanum* Cobb, the dagger nematode) that live on biennual or perennial hosts may be more or less active even through off-season periods, unless frost and extreme heat induce them to dormancy.

All plant nematodes appear to be aerobic; lack of oxygen induces sluggishness. Since soil air has a great amount of CO_2 the actual respiratory needs of plant nematodes, and their methods of meeting these needs, are unsolved problems.

The pH conditions of a soil do not appear to be selective or conditioning factors of much significance for plant nematodes. Early claims that high alkalinity of a soil reduces the incidence of root-knot nematode infestions have not been confirmed by later tests.

Brackish soils appear to have specific forms of plant parasitic nematodes. The Ditylenchus or stem nematode which attacks marine plantain is an example of such specificity. It is not *Ditylenchus dipsaci*, the bulb or stem nematodes as considered formerly.

In a discussion of soil conditions that affect plant nematodes biotic factors should not be forgotten. The edaphon of any soil usually includes

a variety of organisms that are either propitious, neutral, or inimical to plant nematodes. Mention should be made of fungi, particularly of those that trap nematodes, of bacteria that cause disease in plant nematodes, of insects, mites, tardigrads, millipedes, earthworms, predatory nematodes and protozoans that feed or cause disease on them. In this regard one should never forget that the relationship of two organisms is always modified by the presence of a third one and that a multitude of organisms in any association makes for extreme complexity. All these relationships are of a more intense character in the soil because of a more effective intermediary than outside the soil. Most important too are the biotic products which abound in any living soil. Such products may be synnemic, neutral, or antinemic. Little research has been done concerning such compounds as produced by plants or various soil organisms. Lichens, e.g. are known to harbor few nematodes. Antibacterial action of some of the metabolic products of these plants has been studied and established, but no work has been done on a possible antinemic action. Such action certainly is suggested by the aforementioned observation of repellancy of nematodes by lichens. Preliminary tests by a staff member of our Division have given indications that some of the medical antibiotics (particularly streptomycin) are lethal to plant nematodes.

No studies have been made to correlate the occurrence of nematodes in general, and of plant parasitic forms in particular, with the redox potential of their environmental soil. Such a correlation has been shown to exist in the occurrence of earthworms. Observations support the assumption that plant nematodes in general shun putrifying environments.

Colloidal conditions of a soil and their relation to plant nematodes likewise have not yet been investigated.

It thus becomes evident that in general soil factors that favor plants also are optimal for plant nematodes. But in the end the presence or absence of a host plant governs all these factors.

If the host plant is a crop grown in monoculture optimal conditions for the attacking plant nematodes are created. If, however, the host is one of a mixed population of plants such optimal conditions are modified and a more complex situation is established. The various component plants of a mixed vegetation usually differ in their effect and influence upon nematodes; they again may be partly neutral, partly inimical and partly propitious. The host plants that may be present in such a mixed vegetation may also possess varying degrees of preference for the nematode. Thus a complexity of neutral, antagonistic and synergistic factors may result, all acting through the intermediary soil. To exemplify a factor of this kind reference is made to the mustard, which has been found to inhibit the hatching of larvae of the golden nematode of potatoes from their cysts. Ellenby has identified this inhibitory agent produced by mustard as allyl isothiocyanate.

Attention should also be called to the fact that soil amendments such as fertilizers, compost, manure, lime, and trace elements, as well as cultural treatments, such as plowing, disking, irrigation and spraying, likewise influence and modify the relationship of a soil to its plant nematode population.

Thus the investigator working with a segment of soil life as here discussed is confronted with an extremely complex situation. Results of experimental tests with single factors of such a complex may only cau-

tiously be integrated into this network of interrelations and must be prudently interpreted in the framework of the whole.

Another fascinating subject for the investigator is the adaptation to life in the soil shown in plant nematodes. The soil may be said to have had a selective and formative influence on these nematodes, specifically on their soil phase. First to be mentioned is the prevalence of an eel-shaped body, a shape considered excellently fit for life in soil. Various plant parasitic nematodes, however, would seem to be exceptions to this characteristic since their body is lemon-, pear-, apple-, kidney-, spindle- or otherwise globularly shaped (e.g. the various heteroderas, the root-knot nematodes, etc.). The deviation in shape in these forms is restricted to the parasitic stages which are sedentary on, or in, the plant host, while the soil phase, comprising the preparasitic larval stage and the adult male, is still eelshaped. It is the sedentary mode of parasitism in all these instances that brought about the loss of the eel-shaped body form. The ring nematodes (Criconematidae) also present a deviation from this fundamental eelshaped body form. Here the plump and stout body, incapable of effective locomotion by undulating movement offers another kind of adaptation to the life in soil. The cuticle of the body surface has retrorse folds arranged in rings which have various types of edges or scale-, flap-, spine-, or fin-like processi. In locomotion, which is accomplished by alternating axial contraction and expansion, these retrorse structures stem against the surrounding soil particles. Thus these plump plant parasitic nematodes are conditioned for a life in soil through the acquisition of these ring structures. The almost complete absence of setae and appendages on the body of plant nematodes is also interpreted as an adaptation to life in soil and similarly the absolute absence of eye spots. Eye spots are not infrequently seen in aquatic nematodes. A further example of the effect of soil life is demonstrated by the amphids, a chemical sense organ present in all nematodes. In aquatic nematodes the openings of these amphids are usually wide, but in plant parasitic forms they are narrow, pore- or slit-like. This obviously prevents their becoming clogged by soil particles. But these respective openings of the amphids are also adapted to the difference in dilution of chemical messengers that are perceived by these taste-bud-like organs. These chemical messengers are concentrated in a soil solution but much diluted in open water. Amphids are also remarkable in some plant parasitic nematodes, e.g. the root-knot nematodes, because of the sexual dimorphism shown. In the male root-knot nematodes these organs are not only larger but of a more complicated structure than in the female, presumably because the male has to locate its sexual partner and therefore needs a highly effective apparatus to do so under soil conditions. It would be enticing to dwell further and in more detail on the many more relationships commonly termed adaptations that are established between the soil as a life medium and the plant nematodes therein.

HOW PLANT NEMATODES AFFECT THE SOIL

Even though the number of plant nematodes in a soil may amount to millions per square meter, their influence on the physical make-up of this soil, as far as now known, appears to be of minor significance. Unlike earthworms they do not seem to modify the structure of a soil nor to have

other noticeable physical effects. Their influence on the chemical condition of a soil has not been studied; it is likely that such an influence is exerted mainly by metabolic products, which in themselves have not yet been investigated. However, attention must be called to an indirect but most significant effect of these nematodes upon a soil, — that nematode infestation can closely simulate a soil defect. Often has growth failure of a host crop been attributed to a lack of productive faculties of the soil rather than to a nematode infection of the crop. Terms like "beet tiredness", "potato tired soil", "sick soil", "sorry soil", illustrate best the conditions of a soil infested by certain and specific plant nematodes. As previously stated, these pests may simulate a variety of conditions that wrongly are attributed to the soil itself. Thus lack of vigor in an effected crop simulates infertility of the soil; plants with nematized roots, because they easily wilt, simulate lack of moisture in the soil; chlorosis in plants, caused by nematodes, may simulate mineral disturbances.

CONTROL OF PLANT NEMATODES AS A SOIL PROBLEM

As previously stated control of plant nematodes is accomplished mainly by their elimination from infested soils. This of course applies only to those nematode pests that have a soil phase. In certain instances special steps have to be taken to assure that the entire infestation is in this soil phase. For example in the case of root knot the efficacy of certain control measures is increased if infected roots and plant parts have decayed, so that eggs and larvae are free in the soil. But it is not our intention to discuss here the control of plant nematodes by soil treatments as such; this is today a very extensive subject. However, attention is called to the significance of soil factors in all these procedures and treatments. These factors involve many different features and aspects of soils, such as soil profile, soil type, soil structure, air space, organic matter, temperature and moisture. In this field there is a particular need for cooperation of soil science and nematology. This need may further be exemplified by reference to a special problem, — that of the so-called stimulation of plant growth that soil fumigation frequently causes on treated land. Soil scientists have investigated this stimulation assuming it to be a chemical problem, involving e.g. the increase of available nitrogen through fumigation. The results as far as known to us have been negative. We are inclined to see in this stimulation rather the effects of a broad control of various crop antagonistic biotic factors, particularly that of a variety of plant nematodes other than, or in addition to, the one the fumigation attempted to control. It should be emphasized that any land usually carries a multitude of types of plant nematodes. In fumigation treatments the effect of control of these additional pests must not be overlooked; their elimination may partly or wholly account for this so-called stimulation.

In conclusion let us emphasize again that the factor nematode is a significant one in any study involving crop behavior in relation to soil; it should never be neglected.

SOME NEW NEMATODE SPECIES OF CRITICAL IMPORTANCE TO FLORIDA GROWERS

J. R. Christie *

Past experience with such insects and diseases as the Japanese beetle, chestnut blight, and the Dutch elm disease, causes people to hear, with some apprehension, reports of new pests. However, when we speak of a pest as being new we may not mean, necessarily, that it is a newcomer, or something that has recently arrived. Some of them, to be sure, are new in this sense of the word but more frequently they are organisms that are native to the region where they are first found or, in any event, have been there for a very long time. What we do mean is that they are organisms only recently recognized as causing injury to crops. It very frequently happens that the injury they cause is not new at all, having long been known to those engaged in growing these crops but with the cause a subject of conjecture and debate.

We have in Florida several plant nematodes that are new in this restricted meaning of the word, and some of them are pests of major importance. Two or three of these probably were introduced into North America from other parts of the world but, if so, this happened many years ago and they are, by now, quite widespread. The others, in all probability, are indigenous to the southeastern states.

Hence, in reporting on these new pests, we are not suddenly confronting growers with new problems but are merely throwing new light on what are, for the most part, old problems of long standing.

To this reassuring thought we must, however, add certain qualifications. Although the situation caused by the presence of these plant nematodes is not new, there seems reason to believe that the resulting crop losses are gradually becoming greater. The longer an area is in cultivation the more serious plant nematodes are likely to become, especially if susceptible crops are grown repeatedly on the same land. If some of these nematodes are indigenous to Florida, and it seems probable that such is the case, they must be feeding on certain native plants; must, in fact, have been feeding on these plants for countless centuries. In such a situation we cannot be sure that virgin land, when cleared and planted for the first time, will be necessarily free from these pests.

THE STING NEMATODE, *Belonolaimus gracilis*

Before a meeting of this Society held during December 1942, Steiner presented the first report on the sting nematode as a plant pest and the original description of the species was published in the Society's Proceedings (13). His report was based largely on the damage this nematode was causing to seedlings of the slash and longleaf pines growing in Florida's forest nurseries. Since this first report the sting nematode has acquired considerable prominence in the southeast where it has been found causing damage to quite a large number of crops growing in widely separated localities (1, 4, 6, 8, 10).

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The sting nematode is a large slender worm that reaches a length of nearly $2\frac{1}{2}$ millimeters. It feeds at root tips and along the sides of succulent roots, mostly from the outside, by inserting its long slender stylet. It devitalizes the root tips and causes necrosis and discoloration that sometimes becomes quite extensive. In general, it is not a lesion nematode, although sometimes affected roots show lesions caused, perhaps by the combined action of the nematode and certain fungi.

Figure 1.—A celery field near Sanford showing areas of stunted plants due largely to injury by the sting nematode.

Root symptoms vary considerably, depending on the kind of plant and the age of the plant at the time when the injury first becomes severe. When the growth of a root tip is stopped, branches develop and the growth of these may likewise be stopped. This repeated branching may result in a small, dense root system composed of short, stubby roots sometimes arranged in clusters (Figs. 2 and 3). If the lateral roots are destroyed almost as soon as they start to form the result may be an open system with the main roots largely devoid of branches. The sting nematode has a tendency to feed close to the base of the stem, killing roots while they are very short. Seedlings and newly set transplants may become almost devoid of a root system and, if not killed, may stand in the field for months and make little or no growth. Ordinarily this nematode does not cause swelling or galls, although on some plants such as corn, the ends of the roots may show gall-like enlargements caused by the repeated forming and killing of new branches.

Crops known to be severely injured by the sting nematode are corn, celery (Fig. 1), beans, soybeans, cowpeas, peanuts, millet, and straw-

berries. Crops known to be injured at least to a moderate degree, some of them perhaps severely enough to be included in the first list, are cotton, peppers, squash, escarole, sorghum, onions, and pine seedlings.

Figure 2.—Root system of a celery plant severely injured by the sting nematode.

The present known distribution of the sting nematode in the Southeast in confined to Virginia, South Carolina, Georgia and Florida. It is widespread in Florida, apparently occurring over most of the state but it has not been found in muck or marl soils. Without much doubt, the sting nematode causes greater financial losses to Florida's vegetable and strawberry growers than any other plant nematode.

THE AWL NEMATODE, *Dolichodorus heterocephalus*

At the time when the sting nematode was first discussed, Steiner reported the presence in Florida soils of another species, the awl nematode (13). In many respects these two are much alike. They are similar in size, shape, and general appearance, they have about the same feeding habits, and they inflict about the same kind of injury to the roots of plants. There are, however, certain differences. Whereas the sting nematode is most likely to be found in light sandy soil, the awl nematode normally is an inhabitant of swamps, marshes and wet locations. Although it can live and thrive in tilled fields, conditions are most favorable for it when the moisture content of the soil is high.

As to what crops are susceptible to attack by this parasite, about all we know is that corn, celery, and tomatoes may be severely damaged

(11. 15). In one instance it was found injuring the roots of Chinese waternuts, *Eleocharis dulcis* (14).

Figure 3.—A portion of the root system seen in Figure 2 shown enlarged.

The awl nematode may not be extremely common in Florida and at present it is not known to be important anywhere except in the Sanford area where it injures corn, celery, and probably some other crops. In this area it becomes serious only in occasional fields but where it occurs

in large numbers, it can be very devastating. Oddly enough, it has not yet been found in muck.

THE STUBBY-ROOT NEMATODE, *Trichodorus* spp.

Newest of all the plant nematodes are the members of the genus *Trichodorus.* Several of these stubby-root nematodes occur in the United States and at least two occur in Florida, but only one appears to be common or widespread in the State (5). This stubby-root nematode is a small form, adults reaching a length of slightly less than one millimeter. It feeds almost exclusively at root tips, devitalizing the tips and stopping growth but, as a rule, not causing extensive necrosis and discoloration. Although symptoms of root injury vary somewhat, a small root system composed of numerous short stubby branches, is the usual condition (Fig. 4). Crops known to be severely injured are beets, corn, celery, cabbage, cauliflower, tomatoes, and chayotes. Crops known to be injured at least to some extent, include beans, cotton, English peas, peanuts, pepper and onions.

Figure 4.—Root system of a corn plant injured by a stubby-root nematode.

This stubby-root nematode is common in Florida, probably being more widespread than the sting nematode. Most of its known distribution is in sandy soils but it has been found in the muck soil of the Zell-

wood area. Stubby-root nematodes, though perhaps not the same species that occur in Florida, are said to be causing damage to crops growing on muck in other parts of the country.

The stubby-root nematodes are very elusive. Soil populations, as evidenced by examination of soil samples taken from around the roots of affected plants, may not be very high even where injury to the plants is severe. Soil populations can build up quickly and may decline with equal abruptness.

Stubby-root nematodes probably cause far greater damage to corps in the South than is generally realized, even by those of us who are more or less familiar with the known facts. Although capable of causing spectacular injury, these nematodes attain their greatest importance as debilitating factors over large areas, causing moderate injury that only occasionally becomes severe enough to attract attention.

THE DAGGER NEMATODES, *Xiphinema* spp.

In the report to which I have already referred (13), Steiner mentioned, briefly, species of the genus *Xiphinema* as being plant nematodes the grower should know. During the past few years there has been accumulating an impressive volume of evidence, indicating that these dagger nematodes are capable of inflicting extremely severe injury to the roots of plants and that they are parasites of major economic importance. About sixteen different species have been named and described and at

Figure 5.—Root of the laurel oak showing injury believed to be caused by the American dagger nematode. A part of the roots is shown enlarged at right.

least three occur in Florida but only one of these appears to be common and widespread. This one might appropriately be called the American dagger nematode since its Latin name is *X. americanum*.

Whereas the sting, awl, and stubby-root nematodes are important parasites of annual crops, including winter-grown vegetables, the American dagger nematode appears to be important as a parasite of trees and shrubs. It is consistently associated with a type of injury that is very common on the roots of the laurel oak, *Quercus laurifolia*, in central Florida. The same nematode has been found associated with somewhat similar injury to the roots of azaleas growing in the same region and to the roots of pecan seedlings growing in Alabama. Affected roots of oak trees show extensive superficial necrosis and are largely devoid of small rootlets except for occasional clusters of short, stubby branches (Fig. 5).

Although sometimes occurring around the roots of corn, oats, and some of the grasses, we rarely find this dagger nematode in Florida soils that are devoted to the cultivation of vegetable crops. The evidence that this nematode is causing the injury with which it is found associated, while very convincing, is, nevertheless, circumstantial and has not been verified experimentally.

THE ROOT-KNOT NEMATODES, *Meloidogyne* spp.

In discussing new species of plant nematodes at least brief mention must be made of root knot. This is a very old disease, having been known for almost a century and over the years there has been built up concerning it a very considerable literature. This literature has been based on the hypothesis that there is only one species of root-knot nematode. This was an error, a mistake so serious that it virtually invalidates part of the literature and detracts very greatly from the value of the remainder.

Probably no subject in biology has its literature more riddled with apparent discrepancies and contradictory results than is that dealing with root knot. This is especially noticeable in reports on the comparative susceptibility and resistance of different plants. One investigator finds that a certain species or horticultural variety of plant is resistant to root knot or only slightly affected by it, while another investigator finds the same plant to be highly susceptible and severely injured (16). We know now that at least six different species or subspecies of root-knot nematodes occur in the United States (2, 3). The reason why investigators got conflicting results becomes easy to understand, for all were not dealing with the same organism.

Thames' root-knot nematode is *Meloidogyne arenaria* subsp. *thamsi* and I mention it first because probably it is commoner and more widespread in Florida than any of the others. It has not yet been reported as occurring anywhere else but undoubtedly it has a wider distribution than our present limited records indicate.

The cotton root-knot nematode, *M. incognita acrita*, also is common in this state and probably ranks second to Thames' root-knot nematode in importance. The cotton root-knot nematode is common throughout the Southeast where it is responsible for much of the root knot damage to cotton.

The southern root-knot nematode, *M. incognita* subsp. *incognita*, probably is more common and widespread in the United States than any of the others and it is at least fairly common in Florida.

The Javanese root-knot nematode, *M. javanica*, has been reported from enough different locations in Florida to indicate that it is at least fairly common. This is the species that infects certain oriental peaches such as Yunnan and Shalil which, otherwise, are root-knot resistant.

The northern root-knot nematode, *M. hapla*, has been found twice in Florida, once on tomatoes from an Orlando garden and once on gladiolus in the Hastings area. No doubt it occurs elsewhere but it is neither common nor widespread. This is the prevailing root-knot nematode of the Northeast, but it has become fairly widespread in the South. It is one of the two root-knot nematodes that infects peanuts and has been found on this crop in Virginia, North Carolina, and Alabama.

The peanut root-knot nematode, *M. arenaria* subsp. *arenaria*, is the other one that infects peanuts. Neal is supposed to have found it infecting this crop near Archer, Florida in 1889 (9) and there have been a few records subsequently of its occurrence in the state. This nematode occurs on peanuts over a considerable area in southwest Georgia and southeast Alabama and undoubtedly extends into northern Florida.

The southern and the cotton root-knot nematodes tend to produce large massive galls. When you find a plant with huge, sweet potato-shaped galls, one or the other of these two subspecies is likely to be involved. Thames', the Javanese and the peanut root-knot nematodes also produce fairly large galls. The northern root-knot nematode produces small galls, mostly on the fine roots. Furthermore, this species stimulates the formation of branch roots, resulting in a dense, reticulate type of root system with many of the galls located in the axils of the branches. However, there is much variation in the type of galling, depending on the kind of plant and other factors, and while the northern root-knot nematode often can be recognized on the basis of galling it is the only one where this is likely to be possible.

Each of these different kinds of root-knot nematodes infects many different kinds of plants, how many and what all the plants are we do not yet know. Many plants are susceptible to all six of these nematodes but this is not always the case; some plants are susceptible to some of them but not to others. Peanuts, for example, are susceptible to two, the northern and the peanut root-knot nematodes, and are resistant to all the others. Cotton is susceptible to the cotton root-knot nematode and more or less resistant to the others. Hairy indigo appears to be a very satisfactory root-knot resistant cover crop for Florida but, according to Machmer (7), it is not resistant to the peanut root-knot nematode. Cucurbits are notoriously susceptible to root knot but, according to Sasser (12), the northern root-knot nematode does not infect watermelons.

Most of the root-knot injury to crops in Florida is caused by one or another or a combination of three subspecies, Thames', the cotton, and the southern root-knot nematodes. Injury by the Javanese root-knot nematode probably is fairly common and injury by the northern root-knot nematode occurs occasionally. The peanut root-knot nematode does not appear to be common in peninsula Florida but this estimate may be the result of insufficient information.

Back in the days when all the root-knot nematodes were believed to be one species and the only one of much importance in this region, the nematode problem had the appearance of being comparatively simple. Symptoms were easy to recognize and we could advise growers regarding the cause of their trouble with considerable confidence, although the control measures we were able to recommend left a good deal to be desired. Recognition of all these new species complicates the situation. No longer is it so easy to advise growers regarding the cause of their troubles. Some of these nematode diseases are elusive and not always easy to recognize on the basis of symptoms.

The picture, however, has a brighter side. While these recent disclosures have introduced new complications they have, at the same time, greatly clarified the situation and this should pave the way for the development of control measures that will be much more effective than any we have had in the past. Soil fumigation, the most dependable control measure known, appears to be effective against all these different nematodes. This phase of the subject will be discussed by others who follow me on the program.

Controlling nematodes by crop rotations and other cultural practices has been, to say the most, only moderately successful. Considering the nematode problem as a whole, such control measures of this kind as we were able to recommend, on the basis of past knowledge, have been far from adequate. Some of the reasons for this inadequacy are especially apparent in Florida where the kinds of resistant crops that can be used in rotations are limited by climatic conditions, where crops frequently are injured by a complex composed of several different kinds of nematodes, and where, in many instances, long periods between cash crops are not economically feasible. Without doubt very substantial improvements in the efficacy of control by cultural practices is possible but before this can be achieved much more information is necessary, especially information on that all-important aspect of the problem known to biologists as host-parasite relationships. Even for the root-knot nematodes, much more information is needed regarding the comparative susceptibility of different plants to the different species and subspecies of this pest.

The root-knot nematodes, like all other nematodes, reproduce by eggs and in no other manner. The extent to which a crop becomes infected depends on how many eggs were laid by the female parasites which infected the crop or weeds that grew on the land previously. If a plant is a highly suitable host for a particular species of root-knot nematode, the females will lay eggs freely even though the roots may not necessarily be severely galled. If a plant is an unsuitable host the females will lay few eggs even though the roots may be severely galled. In other words, the extent to which the roots of a crop become galled is no indication of the extent to which the parasites will lay eggs and reproduce, and, therefore, no indication of the extent to which a following crop will become infected. This habit of these nematodes to reproduce freely on some plants without causing conspicuous galling and to cause conspicuous galling on other plants without reproducing freely is one of the reasons why the occurrence of root-knot has come to be regarded as unpredictable.

For much the same reason, the extent to which a crop is injured by the sting or by the stubby-root nematodes is determined, in part at least, by the kind of vegetation that previously grew on the land. The sting

nematode, for example, feeds on and injures many different kinds of plants, but it reproduces more rapidly when it feeds on some kinds than when it feeds on others. The extent to which a particular crop will be injured by an existing population of one of these nematodes and the extent to which this crop will serve as a build-up host for this same nematode is a distinction which investigators should bear in mind.

We need to know the comparative rate at which each of the different nematodes will reproduce and how their populations will build up on different plants, including both crop plants and weeds. Flooding or keeping the soil saturated with water is a procedure that many vegetable growers have used to good advantage in reducing the severity of damage by root knot. Obviously this procedure will not control the awl nematode but to what extent it may be effective in controlling some of the others remains to be determined. Most nematodes are sensitive to drying and dry tillage, e. g., withholding water and tilling the soil while it is dry is a procedure that merits investigation.

The problem of controlling nematodes is not an easy one and much needs to be done, but the rewards for success will be very great and could have a far-reaching effect on the agricultural economy of the state.

LITERATURE CITED

1. Brooks, A. N. and Christie, J. R. 1950. A nematode attacking strawberry roots. Proc. Fla. State Hort. Soc. 123-125.
2. Chitwood, B. G. 1949. Root-knot nematodes. Part I. A revision of the genus *Meloidogyne* Goeldi. 1887.
3. Christie, J. R. and Albin, F. E. 1944. Host-parasite relationships of the root-knot nematode, *Heterodera marioni*. I. The question of races. Proc. Helminth. Soc. Wash. 11 (1): 31-37.
4. ——————, Brooks, A. N., and Perry, V. G. 1952. The sting nematode, *Belonolaimus gracilis*, a parasite of major importance on strawberries, celery, and sweet corn in Florida. Phytopath. 42 (4): 173-176.
5. ——————, and Perry, V. G. 1951. A root disease of plants caused by a nematode of the genus *Trichodorus*. Science 113 (2937): 491-493.
6. Holdeman, Q. L. and Graham, T. W. 1952. The association of the sting nematode with some persistent cotton wilt spots in northeastern South Carolina (abstract). Phytopath. 42 (5): 283-284.
7. Machmer, J. H. 1951. Root-knot of peanut. I. Distribution. Plant Disease Rept. 35 (8): 364-366.
8. Miller, L. I. 1952. Control of the sting nematode on peanuts in Virginia (abstract). Phytopath. 42 (9): 470.
9. Neal, J. C. 1889. The root-knot disease of the peach, orange, and other plants in Florida due to the work of the Anguillula. U. S. Div. Entomol. Bull. No. 20, 31 pp.
10. Owens, J. V. 1951. The pathological effects of *Belonolaimus gracilis* on peanuts in Virginia (abstract). Phytopath. 41 (1): 29.
11. Perry, V. G. 1953. The awl nematode, *Dolichodorus heterocephalus*, a devastating plant parasite. Proc. Helminth. Soc. Wash. (In press).
12. Sasser, J. N. 1952. Identification of root-knot nematodes (*Meloidogyne* spp.) by host reactions. Plant Disease Rept. 36 (3): 84-86.
13. Steiner, G. 1942. Plant nematodes the grower should know. Proc. Soil Sci. Soc. Fla. IV-B: 72-117 (Issued Apr. 1, 1949). Idem 1949. Fla. Dept. Agr. Bull. No. 131 (n. ser.).
14. Tarjan, A. C. 1952. Awl nematode injury on Chinese waterchestnuts (abstract). Phytopath. 42 (2): 114.
15. ——————, Lownsbery, B. F., and Hawley, W. O. 1952. Pathogenicity of some plant-parasitic nematodes from Florida. I. The effects of *Dolichodorus heterocephalus* Cobb, on celery. Phytopath. 42 (3): 131-132.
16. Tyler, J. 1941. Plants reported resistant or tolerant to root-knot nematode infestation. U. S. Dept. Agr. Misc. Publ. No. 406, 91 pp.

SOIL FUMIGATION FOR THE CONTROL OF PLANT PARASITIC NEMATODES

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All cultivated land in Florida contains plant parasitic nematodes and each cultivated crop is a suitable host for one or more nematode species. Some crops, of course, are rarely injured severely and some of the plant parasitic nematodes are only mild parasites. Many vegetable crops, however, are severely injured by several destructive nematode species that are widespread in Florida, and in certain areas some crops can be successfully grown only if the nemic diseases are controlled. Many of the sandy soils that are irrigated and continuously cropped harbor enormous numbers of such devastating parasites as the sting nematode, the stubby root nematode, and the root-knot nematodes. The stubby root nematode, for example, is so abundant in these soils that anyone who attempts to grow sweet corn is likely to find nematode control a necessity.

Soil fumigation with one of the recommended fumigants is the most effective and dependable means known at the present for controlling soil borne nematodes. Other control measures such as crop rotation and flooding may be used effectively in some instances but cannot be generally recommended, since we know very little about the host range and environmental requirements for such major nemic pests as the sting nematode and the stubby root nematodes. The soil fumigants will kill all the plant parasitic nematodes known to occur in Florida.

The fumigants apparently react differently with different soil types and for that reason this discussion will be limited to fumigation of the sandy soils. For all practical purposes the same procedures should be followed when the fumigants are applied to other soil types such as muck. The chemicals tend to persist for a longer period in the organic soils and nematode control is somewhat lower than on the sand lands.

THE DEVELOPMENT OF SOIL FUMIGATION

Attempts have been made to control nematodes with various chemicals almost from the time they were discovered as plant pathogens but the first really effective material to be used was chloropicrin. In 1919 Matthews (3) reported excellent control of the root knot nematode with chloropicrin. His results were later confirmed by other workers and in 1937 the material was introduced as a soil fumigant by Innis, Speiden and Company. It was first used, by nurserymen and greenhouse operators, as a substitute for steaming. Chloropicrin was later used to control soil organisms in the pineapple fields of Hawaii and for some crops in California. In 1941 Taylor and McBeth (8) proposed the spot method of fumigation, wherein chloropicrin was used to fumigate small areas for the planting sites of crops grown in widely spaced hills. They also suggested that row fumigation be considered for row crops.

Taylor and McBeth (6) in 1940 reported excellent results in controlling nematodes with methyl bromide, provided the gas could be

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confined in the soil for a short period. They reported later (7) that a mixture containing 10 percent methyl bromide in other less volatile liquids was also effective. However, methyl bromide is comparatively expensive and when injected into the soil in the usual way it often gives poorer results than some of the less expensive fumigants. Methyl bromide mixtures intended for application in this manner are no longer on the market. Tests at various experiment stations in cooperation with the Dow Chemical Company have shown that by evaporating methyl bromide at the surface of the soil under a gas tight cover the potential killing power of this chemical can be utilized to a greater extent than by injecting it into the soil. This has proven to be a very effective way of treating seedbeds and other small areas.

Figure 1.—A celery field near Sanford of which the area on the right was fumigated. The pronounced improvement in growth on the fumigated area was due largely to control of the sting nematode, *Belonolaimus gracilis*, but a stubby-root nematode, *Trichodorus* sp., was present also in damaging numbers.

Carter (1) in 1943 reported that a crude mixture of dichloropropene and dichloropropane obtained from the Shell Development Company was a very good nematocide. Others soon confirmed his results and this material was introduced commercially in Florida as "D-D" in 1945. This was the first really effective nematocide found that was inexpensive enough for general field use.

Then in 1945 Christie (2) reported that ethylene dibromide (EDB) gave excellent control of the root-knot nematodes in preliminary tests. The Dow Chemical Company was also testing EDB and soon introduced

it as a low cost fumigant under the trade name Dowfume W. Other companies were soon marketing EDB under various trade names.

Since 1945 the control of plant parasitic nematodes has attracted the attention of various agricultural workers and chemical companies. Hundreds of chemicals have been screened for possible nematocidal action but at present none have been introduced to compete with D-D and EDB for field scale application. Recently the Shell Chemical Corporation has introduced chlorobromopropene or "CBP Emulsible," a combination nematocide-fungicide-herbicide fumigant intended primarily for seedbed, nursery, and greenhouse use.

Figure 2.—Celery plants from the field shown in figure 1, the plant on the left from the fumigated area, the one on the right from the unfumigated area. Not all the plants on the unfumigated area were damaged and stunted as severely as the one shown but a great many of them were.

All the above materials are used in Florida, but the cost of chloropicrin, methyl bromide, and CBP Emulsible is prohibitive except for seedbeds or small areas where crops have exceptionally high value. The remainder of this discussion will be devoted largely to D-D and EDB fumigants and their application.

The use of D-D and EDB has increased tremendously during the past few years because in many instances it has brought about astonishing improvement in the growth of plants. Many growers have adopted soil fumigation as a general practice.

Formulations of the two chemicals have changed very little since their introduction. D-D is marketed in substantially the original form

which is a mixture containing about 50 percent of the active ingredient and it is applied as received without diluting.

EDB fumigants are mixtures of ethylene dibromide and naphtha or a similar petroleum distillate. They are sold under various trade names, the only important difference between them being the amount of ethylene dibromide they contain. Those intended for field application contain either about 40 percent or about 85 percent ethylene dibromide by weight. The more concentrated mixtures are preferred where applicators are available that will deliver small quantities of liquid accurately. An emulsifiable form of EDB has been developed so that water may be used as a diluent.

APPLICATION OF D-D AND EDB TO THE SOIL

The proper application of D-D and EDB to the soil is perhaps the most important step in achieving good nematode control by soil fumigation. Both are volatile chemicals that kill the nematodes by diffusing through the soil in a gaseous state. They must penetrate throughout the top 8 to 12 inches of soil before escaping into the air or else a high percentage of the nematodes will survive. Rate of application, depth of application, soil moisture content, soil temperatures, properly functioning applicators, and the physical condition of the soil are some factors that affect the efficiency of soil fumigation.

The rate of application is determined by the method of treatment (solid, row, spot, or strip). In the solid treatment method the fumigants are applied in streams about 10 to 12 inches apart over the entire area. This method is by far the most effective under Florida conditions and is recommended for use with all closely spaced crops. In some cases a stream of the fumigant applied along the planting row, called row treatment, will give good control. Most nematodes do not migrate fast enough to move back into the narrow fumigated areas soon enough to prevent root systems from being established. Row treatment is of little value where the stubby root nematode is a major pest but should give good control of the sting and root-knot nematodes, at least during the early stages of plant growth.

The spot and strip methods are variations of the solid method, wherein only the planting sites of widely spaced crops are fumigated. The spot method has been used with considerable success for nematode control with melons and other hill crops. The strip method is used primarily to fumigate grove and orchard areas.

Table 1 gives the recommended rates of both fumigants for each method of application. If other than the 40 percent EDB is used it must be remembered that the percentage of this material is always given by weight. Pure ethylene dibromide weighs about 18 pounds per gallon, or approximately thrice the weight of the naphtha diluent.

For best results the moisture content of the soil should be about the same as that desired for planting seeds, or 10 to 12 percent in Florida sands. If the soil is either too wet or too dry the chemicals will not disperse very thoroughly and a kill is likely to be obtained only in spots. Except during wet spells, light rain following application is desirable, but heavy drenching rains that flood the fumigated area will decrease the kill very substantially. Soil temperatures should be at least 60° F. and

preferably higher. In Central and South Florida soil temperatures are not usually too low for fumigation, even in winter.

TABLE 1.—Recommended Rates for Soil Fumigation.

Fumigant	Method of Application			
	Solid	Row	Spot	Strip
D-D	20 to 25 gals./acre	2 to 3 ml. per ft. of row	2 to 3 ml. per sq. ft.	20 to 25 gals. per fumigated acre
40% EDB	20 gals. per acre	2 to 3 ml. per ft. of row	2 to 3 ml. per sq. ft	20 gals. per fumigated acre

The soil should be in good tilth with clods and undecayed vegetable matter at a minimum. The land should be level, especially if a tractor applicator with several outlet shanks is used, otherwise one or more of the shanks may deliver the fumigant on or near the surface when passing over a low spot or furrow.

In the sandy soils of Florida the fumigants should be delivered at least 6 and not more than 8 inches below the surface. If the fumigants are applied too shallow the gases escape before a good kill is obtained, if too deep, areas at the surface will not be treated.

Various means have been developed for injecting the chemicals into the soil but this discussion is limited to tractor-mounted applicators, the development of which is described by Russell (4). These tractor fumigator kits are available and can be used on all modern farm tractors. Briefly, they consist of a tank for the chemical, a pump operated from the power take-off of the tractor, a metering device to regulate the flow, narrow plow shanks (one for each outlet), a shut off valve, and plastic tubing to carry the chemical from the tank through the pump and metering device to the outlet shanks. The chemical is delivered into the soil directly behind each outlet shank.

The power of the tractor determines the number of outlet shanks that can be used since each shank must extend six or more inches into the soil. Medium sized and larger farm tractors should be able to pull six or more shanks and maintain proper depth.

The metering device permits adjusting the flow of the chemical and thus regulates the rate per acre at a given tractor speed. Manufacturers of the applicator kits provide directions for their installation, operation, rate adjustment, and maintenance. Fumigants, especially D-D, are corrosive chemicals and applicators should be cleaned and flushed with kerosene or tractor fuel immediately after use, even though they may be made from materials resistant to corrosion.

During application the outlets may become clogged from time to time, usually either at the metering device or outlet shanks. The outlets should be checked by releasing a small amount of the fumigant each time they are lifted for turning. The gases will not disperse through the soil for much more than six inches and should a line become clogged, infested strips will be left in the field. These strips will increase in size due to a slow migration of the nematodes after the chemical has dissipated.

Immediately following an application of EDB or D-D the land should be dragged and compacted as an aid in holding the chemicals in the soil. A drag may be attached to the tractor behind the fumigant outlets, provided the tractor has sufficient power. However the dragging is done, it should be thorough and the channels left by the outlet shanks should be completely and firmly filled. Knocking a little loose, dry soil into these is not enough.

Figure 3.—A fumigated celery field near Sanford. The strips of stunted plants are believed to have been caused by failure of one of the applicator nozzles (the one at either the extreme right or left) to deliver the fumigant thus leaving unfumigated strips about 2 feet wide. Improvement in growth resulting from fumigation was due largely to control of the awl nematode, *Dolichodorus heterocephalus*.

It is believed that the fumigants must remain in the soil for a period of about 7 days to give best results. After 7 to 10 days the soil should be harrowed to about the depth of application in order to help rid the soil of the chemical. This step should be omitted when the row or spot treatment method is used, for it cannot be accomplished without reinfesting the clean area. Where aeration is not complete the chemicals may remain in the soil and injure crops.

Plants differ in their tolerance of traces of the fumigants. EDB and D-D are toxic to most plants and some seeds when present in the soil at concentrations necessary to kill nematodes. Even when not killed, upon exposure to the fumes, plants may be severely stunted or delayed in their growth. Therefore, a period of fourteen days, or sometimes even longer, should be allowed before planting fumigated areas. If heavy rains occur or more than the recommended dosages are used, a longer period before planting is necessary. This is particularly true when heavy rains occur and the soil cannot be harrowed for aeration.

At the present time no chemical can be recommended for the control of nematodes on living plants. Some growers in Florida have attempted to fumigate infected plants in the field but for the most part this process results in injury to the plants. In spite of some initial injury, this pro-

cedure appears to have brought about increased root growth in some instances but usually this improvement has not been enough or has come too late to save the crop.

PRECAUTIONS

The fumes of both D-D and EDB should be avoided insofar as possible. If the materials are handled inside a building it should be well ventilated. Either chemical may cause serious burns if spilled on the skin, clothing, or shoes. Exposed skin should be washed with soap and plenty of water. If spilled on clothing the garments should be removed immediately and not worn again until cleaned. Shoes exposed to the chemicals should be removed immediately and not worn again for several days or until all traces of the chemicals have dissipated. Especial care must be taken to prevent the chemicals from coming into contact with the mouth and eyes. A few cases of burns on the bottom of the feet of men working in fumigated areas have been reported.

EFFECTS OF SOIL FUMIGATION

When properly applied to the sandy soils of Florida under favorable environmental conditions, both D-D and EDB should kill 90 percent or more of the living nematodes present. Most of the eggs will also be inactivated. Fortunately, complete eradication of the nemic parasites is not necessary since their reproduction rate is relatively slow when compared to that of other plant pathogens. Populations of some of the nematodes do return to their previous level about two to three months after fumigation; however, this period of six weeks or longer when the soil is relatively free of nematodes, is sufficient time for most annual crop plants to establish a good root system. For the most part in Florida nematode damage is inflicted at or near the root tips so that once a root system is established plants usually escape serious injury. The number of nematodes that older plants which possess abundant root systems will tolerate may be more than enough to inhibit the growth of seedlings.

Oftentimes in Florida, soil fumigation makes the difference between an excellent yield and no yield. It is, however, not a "cure-all" for all soil problems. An appreciable increase in crop yields following fumigation may be expected only when nematodes or certain soil insects, such as wireworms, are present in numbers sufficient to inflict considerable damage to plant roots. The root-knot nematodes produce symptoms easily recognized by anyone familiar with plant diseases but many other species feed on roots without producing clearly defined symptoms. In addition, nematode populations sometimes rise and fall rapidly. For these reasons even the trained nematologist often has difficulty in determining whether or not a field should be fumigated unless he can observe it when a crop is growing.

Past experience with soil fumigation has been largely for control of root-knot nematodes and with these pests one application will not ordinarily protect more than one crop regardless of the rate applied. Hence the most economical procedure is to apply just enough fumigant to protect this one crop and no more and standard recommendations are based on this objective. Following fumigation the nematodes that escape

destruction usually reproduce rapidly because vigorous plants provide them with abundant roots on which to feed. However, the rate at which soil populations of nematodes build up differs with different species. The stubby-root nematode reproduces rapidly and populations may reach damaging proportions in two months after the soil is treated. On the other hand, populations of the sting nematode build up much more slowly and instances have been observed where one application of a fumigant has given good protection to two successive crops, both of which were highly susceptible to injury by this pest.

Most soil scientists agree that partial soil sterilization, such as is accomplished by fumigation, is not harmful to the soil, the microorganism activity, or to crop plants. Populations of beneficial fungi and bacteria may be reduced temporarily but the reproduction rate for these organisms is very rapid under favorable environmental conditions. In some tests soil fumigation has actually increased nodulation caused by the symbiotic nitrogen fixing bacteria.

The active ingredients of the fumigants soon volatilize and leave the soil but some residues may be left from impurities and diluents. Only a small fraction of either remains and this can be reduced by proper aeration of the soil following application. Most cases of crop stunting following soil fumigation are due to improper application or unsuitable conditions. In some cases the nematodes are not effectively controlled due to a high moisture content, low moisture content, a shallow application, etc. Failure to free the soil of the chemicals before planting due to a short waiting period or lack of aeration, will most certainly result in stunted plants during the early stages of growth.

LITERATURE CITED

1. Carter, Walter. 1943. A promising new soil amendment and disinfectant. Science. 97 (2521): 383-384.
2. Christie, J. R. 1945. Some preliminary tests to determine the efficacy of certain substances when used as soil fumigants to control the root-knot nematode, *Heterodera marioni* (Cornu), Goodey. Proc. Helminth. Soc. Wash 12 (2): 14-19.
3. Matthews, D. J. 1919. Report of the work of the W. B. Randall research assistant. Cheshunt Exp. and Res. Sta. Ann. Rpt. 5: 18-21.
4. Russell, J. C. 1952. The development and availability of efficient applicators for use in soil fumigation treatment. Proc. Soil Sci. Soc. Fla. (this issue).
5. Taylor, A. L. 1951. Chemical treatment of the soil for nematode control. Adv. Agron. 3: 243-264.
6. —————— and C. W. McBeth. 1940. Preliminary tests of methyl bromide as a nematocide. Proc. Helminth. Soc. Wash. 7 (2): 94-96.
7. ——————. 1941. A practical method of using methyl bromide as a nematocide in the field. Proc. Helminth. Soc. Wash. 8 (1): 26-28.
8. ——————. 1941. Spot treatment with chloropicrin and ethylene dichloride for control of root-knot. Proc. Helminth. Soc. Wash. 8(2): 53-55.

CONTROL OF CELERY SEEDBED DISEASES BY SOIL FUMIGATION

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Soil fungi and nematodes cause untold damage and loss of seedlings in plant beds in Florida. Interaction of these causal agents makes it difficult to determine what part each plays in this loss. Elimination of either will improve plant stands, but still better stands and growth of seedlings are obtained when both are controlled.

Species of *Rhizoctonia*, *Pythium*, *Fusarium* and *Sclerotium* are the most important fungi causing damping off and root rot of celery seedlings.

Two principal genera of nematodes, *Meloidogyne*, causing root knot and *Trichodorus* (2), causing stubby root, are most commonly associated with root diseases in celery seedbeds.

Recent studies by Nusbaum (9) in North Carolina indicated that Fusarium wilt and black shank of tobacco were greatly reduced in soil fumigated for the control of root knot. Nusbaum concluded, "The control of nematodes may be an important step in controlling other major root diseases of tobacco." McClellan and Christie (5) concluded from their experiments that root-knot nematodes had very little effect on the incidence of Fusarium infection. However, they state, "No conclusions can be drawn regarding the effect of different nematode populations." Smith (11) observed a reduction in cotton wilt where Dowfume W-10 was applied. It is the opinion of many workers that nematodes increase the amount and severity of many root diseases primarily caused by other parasitic organisms.

The production of non-infested seedlings for transplanting is important, because a non-infested field can become contaminated through the use of infested seedlings, and because plants attacked early may be severely affected.

Several fumigants have been commercially available for years but have not been used extensively because of inconvenient method of application, toxicity to operator, specificity and expense. This paper presents briefly some of the developments of soil fumigation as they pertain to disease control in celery seedbeds.

FACTORS INFLUENCING THE EFFICACY OF FUMIGANTS

A number of edaphic factors are important in determining the efficacy of a fumigant. These factors are soil temperature, moisture, composition, type, reaction and aeration. These above factors are briefly discussed because they may determine the success or failure of a given compound and must be taken into consideration when evaluating a soil fumigant. There are at least two main factors which may determine the effectiveness of a fumigant at a given temperature, (1) volatility of fumigant and (2) inherent toxicity of a given concentration towards each of the organisms.

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Florida Agricultural Experiment Station Journal Series, No. 126.

Results of temperature studies are conflicting, but most agree that fumigants should be used at temperatures above 65 to 70° F. Volatility and diffusion are greater at higher temperatures; this may or may not be advantageous, depending upon the chemical properties of a given fumigant. Stark reported (unpublished thesis summarized by Newhall (7)) a significant reduction in efficacy of chloropicrin when the soil temperature at the time of treatment was reduced from 85° F. to 73° F. Parris (10) observed that D-D was effective at soil temperatures as low as 38° F. Newhall and Lear (8) observed that methyl bromide was as effective at 48° as at 60° F. The writer has observed that methyl bromide was equally effective from 48 to 89° F. in sandy soil in central Florida.

McClellan et al (6) in a study of several fumigants against root knot and soil fungi, observed that fumigants were most effective in wet soils, and they were retained longest in wet soils at low temperatures. Newhall (7), reporting on Stark's research, stated that high moisture content, 10 to 15% of soil capacity, is believed the optimum for maximum lethal effect.

The failure of D-D mixture to diffuse through soils in clay or organic material was a partial explanation offered by Allen et. al. (1), for the poor control of the sugar beet nematode in California. Their results showed that a given dosage of D-D mixture appears to be about 100 times more effective in Fresno sandy loam than in Bowers clay or Egbert organic loam, because of its greater dispersal in light soil.

Soil reaction is perhaps the least important edaphic factor affecting the use of a fumigant, since most of them are effective over a wide pH range.

Soil aertion is important with respect to the penetration and escape of the fumigant.

Complete eradication of causal agents is not entirely impossible but highly improbable. However, complete eradication is not necessary for good commercial control.

METHODS OF APPLICATION

The efficacy of the fumigant may be greatly influenced by the method of application. Fumigants giving poor control by the injection method may give good disease control when applied as a drench or as a gas. Four methods of application are briefly described.

Injection

Fumigants are injected into the soil to a depth of six inches with the aid of a hand-operated fluid-injector. Points of injection are spaced at intervals of 12 inches, which is believed to be the maximum distance for effectivness. Fumigation by this method has not proved satisfactory for disease control in celery seedbeds. This failure may be in part due to the specific qualities of the chemical and also to the limited dispersion of the gas in the soil. For exampe, chlorobromopropene was not effective in disease control when applied by the injection method but was effective when applied by the drench method.

Gassing

One material used, methyl bromide, required a cover of gas-tight material. Either polyethylene sheeting or sisal kraft paper is a satisfactory cover material. A space 6 to 8 inches between the soil surface and cover

is necessary for the circulation of the gas. Wooden troughs or metal pans large enough to collect the liquid should be spaced at intervals along the seedbed surface. Saran tubing, through which the liquid flows, should be fastened securely in the containers to prevent the liquid from being sprayed about. The cover spread over the area to be treated must be sealed at the edges with soil to prevent the escape of gas.

This method proved very effective in disease control, but is limited in use to small areas because of the labor involved and the initial cost of equipment.

Application with a Dry Carrier

Vermiculite has been used during the past two years as a carrier for both liquid and solid materials. The fumigant was added to vermiculite in a container large enough for thorough mixing. The mixture was spread over the surface of the soil and tilled in to a depth of 3 or 4 inches. This method, as compared with the injection method, gave a more uniform distribution of the fumigant in the soil. It shortened the distance between points of concentration and gave better results.

Drench

The formulation of many fumigants in emulsifiable (or miscible) forms which can be applied as drenches provides for an even distribution of the chemical in the soil. This, in turn, should increase their effectiveness. The optimum amount of water, yet to be determined, appears important in aiding the dispersion of the chemical through the soil. Water applied with the soil fumigant at the rate of three fourths gallon to two gallons per square yard has given good results in controlling diseases of celery seedlings.

SOIL FUMIGANTS

A study has been made of methods and materials for treating celery seedbeds before a disease develops. Soil fumigants appear to offer a solution to the problem. Since all of the soil fumigants thus far tested are phytotoxic, it leaves no alternative other than to apply them to the soil as pre-planting treatments.

Chloropicrin

Chloropicrin ($C\ Cl_3\ NO_2$) has not been used extensively in seedbed tests because of its high volatility, disagreeable lachrymating effect and excessive cost. Chloropicrin is a colorless, inflammable liquid with a specific gravity of 1.6. Injection of the fumigant, at 2 cc per sq. ft. and sealing the fumigated area with 2 gallons of water per sq. yd., has not given results comparable to other fumigants used in the seedbed tests.

Dichloropropene Dichloropropane

D-D mixture (1,3 dichloropropene and 1,2 dichloropropane) has been used as a soil fumigant for a number of years in celery seedbeds. The mixture is injected into the soil at a depth of 6 to 7 inches and at a dosage level of 20 to 30 gallons per acre.

The material is an excellent nematocide and its properties have been demonstrated in Florida by Kincaid and Volk (4) and Clark and Meyers (3).

Fungicidal properties of D-D mixture are very limited, as demonstrated by Parris (10) when he applied the mixture at a rate of 1000 pounds per acre and it failed to control damping-off due to Rhizoctonia, Fusarium and Pythium. Plant stands and growth of celery seedlings show marked improvement in fumigated areas, as compared with non fumigated areas. However, damping off and red root continue to be a problem in seedbeds treated with D-D mixture.

Ethylene Dibromide

Ethylene dibromide (1.1 dibromoethane) is marketed under several trade names, and is as effective in nematocidal properties as D-D mixture. Like D-D, it has little or no fungicidal value.

Methyl Bromide

Methyl bromide (CH_3 BR) has a low boiling point of 3.6° C. and a high volatility of 1.824 mm. vapor pressure at 25° C. High volatility is an advantage in that it readily penetrates the soil and later diffuses from the soil. Nevertheless, this property is also a disadvantage, since the area being fumigated must be covered to prevent the escape of gas too rapidly.

Methyl bromide was one of the first materials used in soil fumigation that gave control of soil fungi, nematodes and weed seed for a period sufficient to allow the plants to grow to transplanting size. A reinfestation of organisms heavy enough to cause injury to root tips does not occur for a period of 2½ to 3 months.

Effective control of disease organisms has been obtained consistently with a dosage of 1 pound of methyl bromide to 50 square feet. As has been previously pointed out, temperature does not appear to be a critical factor, since good results have been obtained when the fumigant was used at soil temperatures ranging from 48 to 89° F.

Seedlings from areas fumigated with methyl bromide were more than three times as large as plants from non-treated areas. This increase in growth is a direct result of the control of organisms causing root injury.

Methyl bromide is poisonous and precautions as outlined on the manufacturer's label should be closely observed.

Dibromobutene

Dibromobutene (OS-1199) is 80% w of trans 1,4 dibromobutene-2 and 20% w 1,2 dibromobutene-3. The main ingredient in pure form has a melting point of 50° C. and a boiling point of approximately 205° C. Dibromobutene is formulated as a wettable powder and a liquid.

OS-1199, used at 2 and 4 grams active ingredient per sq. ft. with vermiculite as a carrier, controlled soil fungi and nematodes attacking celery seedlings. Its fungicidal properties are slightly superior to the nematocidal properties.

Again the growth of plants in treated areas was more than three times that from untreated areas. This is important, since plants are ready to transplant two to three weeks before those from untreated plots. Moreover, plants from fumigated areas are more sturdy and of better color, and can withstand the shock of transplanting more easily.

The high degree of mammalian toxicity may limit the use of OS-1199 for seedbed fumigation. Extreme caution should be exercised in handling the compound. The material also tends to break down in storage.

Hexachlorocyclopentadiene

Hexachlorocyclopentadiene (P-162) is a liquid with a specific gravity of 1.65 at 74° F. and boiling point of 227° C.

The compound, used at 200 pounds per acre, did not give satisfactory control of damping-off organisms or nematodes causing stubby root. The material does not appear suitable for use in celery seedbeds, because a slight phytotoxic effect was noted at the rate used, even though an interval of two weeks elapsed between treatment and planting.

Chlorobromopropene

Chlorobromopropene (principally 1-chloro-3 bromo-propene-1, CBP-55) is a mixture of chlorinated and brominated hydrocarbons. The material, formulated as an emulsion, contains 38 percent by volume of technical chlorobromopropene. Physical properties vary considerably but typical values are as follows: flash point above 90° F., specific gravity of 1.4, which gives a weight of 11.6 pounds per gallon.

CBP-55, 55 percent by volume, injected into the soil to a depth of six inches, 2 cc per sq. ft., did not control soil fungi or nematodes. Lack of disease control with CBP-55 can undoubtedly be accounted for by the poor dispersion of the fumigant through the soil. Emulsifiable CBP-38, applied as a drench at the equivalent dosage, gave almost complete control.

Results from extensive tests during the summer of 1952 indicate that CBP-38 used at dosage levels of ¾, 1 and 1½ gallons per 50 sq. yds., with water applied at the rate of ¾ to 2 gallons per sq. yard, controlled soil fungi and nematodes attacking celery seedlings. CBP-38 was equally effective over a soil temperature range from 75 to 89° F.

Celery seedlings on the fumigated areas were three times as large as those on the untreated plots.

Chlorobromopropene is poisonous and precautions must be observed to prevent excessive inhalation of the vapors or spillage on clothing or skin.

PLANTING INTERVAL

A two-week interval between treatment and planting is necessary for all fumigants discussed except methyl bromide. For methyl bromide, an interval of 24 to 48 hours following removal of the cover is sufficient to eliminate any danger of phytotoxic reaction from the chemical.

SUMMARY

Soil fungi and nematodes cause considerable loss and damage to celery seedlings grown in seedbeds.

Edaphic factors, including soil temperature, moisture, composition, type, reaction and aeration, have a definite effect on the efficacy of the fumigants.

Four methods of application, injection, gassing, dry carrier and drench, were used in applying soil fumigants to celery seedbeds. These are discussed, giving advantages and disadvantages of each method.

Soil fumigants are discussed, with particular emphasis on the efficacy for control of both fungi and nematodes. Methyl bromide, dibromobutene and cholorobromopropene have given satisfactory control of both types of disease organisms affecting celery seedlings.

LITERATURE CITED

1. Allen, M. W., and D. J. Raski. 1950. The effect of soil type on the dispersion of soil fumigants. Phytopathology 40. 1043-1053.
2. Christie, J. R., and V. G. Perry. 1951. A root disease of plants caused by a nematode of the genus Trichodorus. Science. 113. 491-493.
3. Clark, Fred, and J. M. Myers. 1951. Fumigation and equipment for nematode control in soils for flue cured tobacco. Fla. Agr. Exp. Sta. Cir. S-27.
4. Kincaid, Randall R., and Gaylord M. Volk. 1952. Soil fumigation for Florida shade tobacco fields. Fla. Agr. Exp. Sta. Cir. S-45.
5. McClellan, W. D., and J. R. Christie. 1949. Incidence of Fusarium infection as affected by root knot nematodes. Phytopathology. 39. 568-572.
6. McClellan, W. D., J. R. Christie and N. L. Horn. 1949. Efficiency of soil fumigants as affected by soil temperature and moisture. Phytopathology. 39. 272-283.
7. Newhall, A. G. 1946. Volatile soil fumigants for plant disease control. Soil Science. 61. 67-82.
8. Newhall, A. G., and Bert Lear. 1948. Soil fumigation for fungus control with methyl bromide. Phytopathology. 38. 38-43.
9. Nusbaum, C. J. 1952. Diseases are ganging up on your tobacco crop. Res. and Farming. N. Car. Agr. Exp. Sta. Progress Rpt. 10. 8-9.
10. Parris, G. K. 1945. The nematocidal and fungicidal value of DD mixture and other soil fumigants. Phytopathology. 35. 771-780.
11. Smith, A. L. 1948. Control of cotton wilt and nematodes with a soil fumigant. Phytopathology. 38. 943-947.

THE DEVELOPMENT OF SOIL FUMIGATION EQUIPMENT

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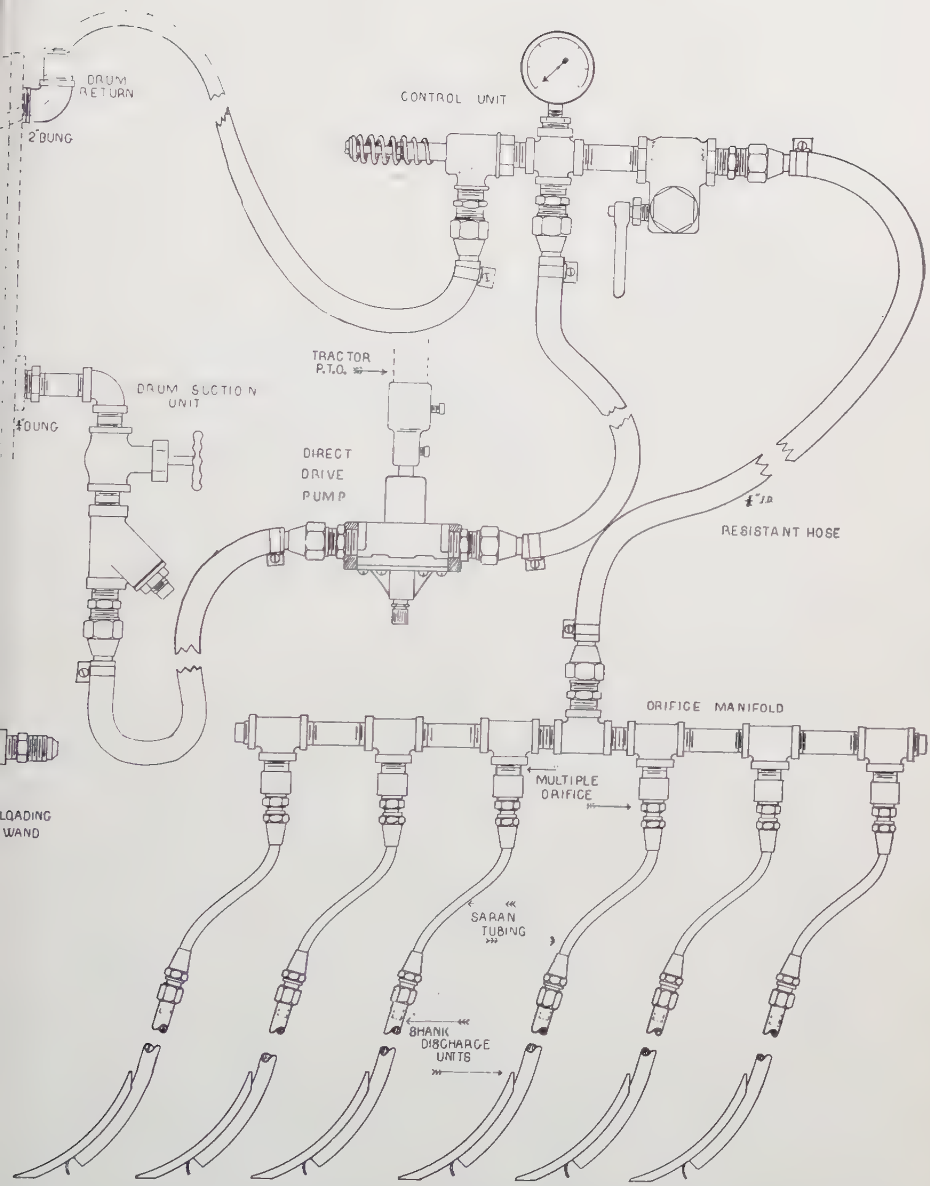
Soil fumigation equipment such as we use today in the application of DD and Ethylene Dibromide has resulted from years of development, trial and error, and engineering skill. Especially over the last seven years, during which time first DD, and later Ethylene Dibromide has been made available to the grower, tractor drawn fumigation injection equipment has gone through many changes from the complicated and expensive equipment first developed and used by Shell, to the more simple and cheaper equipment now on the market.

To go back before the time of DD, the only good chemical nematocide available for many years was chloropicrin. Because of the high material cost very little development of large scale application equipment was undertaken. However, hand injectors such as the Mack Weed gun were developed and served the need quite satisfactorily for some time. In more recent years, improvements over the Mack Weed Gun type injector have been made. Shell Chemical Corporation developed a hand injector constructed of stainless steel and precision built so that extremely accurate delivery is possible. This machine is costly but is widely used for experimental fumigation trials where accurate delivery is imperative. As early as 1935, J. R. Neller and R. V. Allison discussed the developments and use of a machine for the sub-surface treatment of nematode infested Florida muck lands with chloropicrin and carbon bisulfide. In 1943 Inis Speiden developed a two row shank injector, feeding by gravity and mounted on a garden tractor, for the application of chloropicrin to small garden or seed bed areas. These early developments were not used very extensively, but served as a start for equipment development after more economical fumigates were developed. Not until DD was developed was any concentrated effort made on developing field equipment. By 1945 Shell Chemical Corporation developed a tractor drawn cart with applicator, shanks, pumps and tank for soil fumigation and offered the first custom service. The cost of this outfit was $400. Soon several more similar machines were assembled and used by dealers in the Florida area. Walker Fertilizer Company in Orlando built the first tractor drawn soil fumigation equipment to be used in Florida and by 1947 several more were constructed and in use by large Florida growers. These machines were complete and have been operating efficiently ever since; but because of the high cost, from $500 to $800, never became very popular.

By 1949 soil fumigation with DD and Ethylene Dibromide had expanded to such an extent in many areas of the west and southeast, that the first mass production of equipment for application was undertaken. Today there are at least four machinery companies offering both tractor drawn pressure equipment and also less expensive gravity flow kits for application. Four companies now offering fumigation equipment to the growers are Spray-Rite, Oakland, California, Hendrix-Barnhill Equipment Company, Greensville, N. C., Gotcher Engineering and Manufacturing



gure 1.—Assembly diagram of Pressure Applicator Kit, model "B" with multiple orifices.

Company, Clarksdale, Mississippi, and Insect Control Sales and Service, Charlotte, N. C. One of the pioneer companies in the mass production of soil fumigation equipment is Insect Control Sales & Service. The kits offered by them have been the most efficient and economical pieces of equipment ever offered to the growers of the southeast. They started construction of soil fumigation equipment in 1949 and have distributed several thousand in this area since that time.

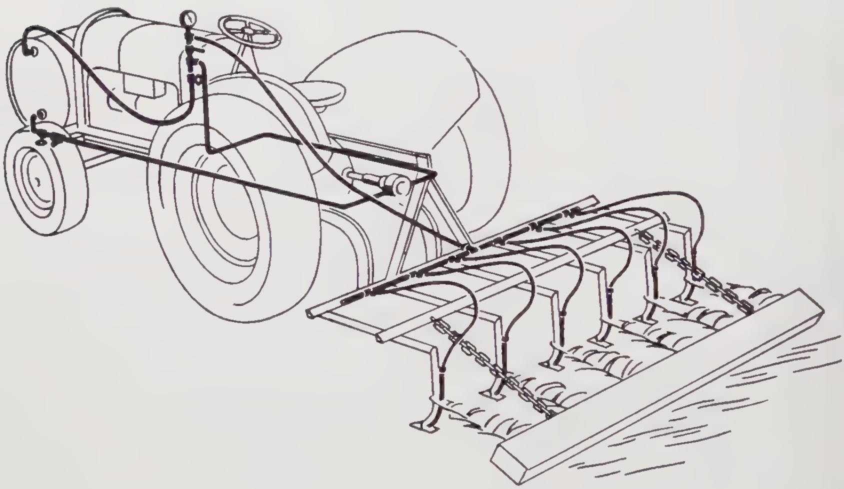


Figure 2.—Insco Pressure Applicator Kit for soil fumigation.

The Insco pressure applicator kit is diagramatically pictured in Figure one which shows all the parts properly assembled. All metal parts of this kit are made of brass which resists the corrosive action of soil fumigants. The saran tubing and plastic lined hose connections also have proven to be resistant to the chemical deterioration of the liquid soil fumigants. The drum section unit contains a cut-off valve and a sleeve strainer. The two units are attached as one piece to the tank, usually a 50 gal. steel drum. The purpose of the cut off valve at this location is so that the flow of liquid from the drum may be stopped while reloading. In order to reload the drum the valve is closed and the hose detached from this assembly. The hose is then attached to the loading wand which is inserted into the small bung of an opened drum standing on end nearby. By running the tractor power take off with the tractor out of gear the pump picks up the fumigant from the stock drum and forces it through the by pass valve into the drum return, thus refilling the tank. The lever cut off valve to the right of the pressure guage naturally must be closed during this operation. It takes about 15 minutes to fill a 50 gal. tank by this method.

The control unit assembly contains the by-pass valve which, with the tractor speed, regulates the pressure as recorded on the guage. The lever cut-off valve is for use in stopping the flow of fumigant when turning or stopping.

The orifice manifold is usually mounted on or near the cultivator shanks. One orifice and assembly is added for each outlet desired. The

orifice assembly consists of a small strainer and a multiple orifice with five different sized orifices. The size orifice to be used is determined by the pressure, speed of tractor and dosage desired. A table has been prepared which makes this determination very simple.

The shank discharge units are mounted on the cultivating shanks.

Figure 2 illustrates one method of mounting for this unit. The kit is easily adapted to any make and model of tractor.

Soil fumigation is a comparatively new farm practice and application equipment has had very little time for development. In spite of this, the equipment now available is very good even though we are sure to see many new improvements within the next few years.

EFFECTS OF DDT, CHLORDANE AND ALDRIN ON NITRIFICATION AND AMMONIFICATION IN ARREDONDO FINE SAND

Harold F. Ross *

New insecticides are being successfully used to control soil-inhabiting forms of life such as wire worm, potato tuber flea beetles and white grubs. Because of this widespread use, the need for a study of their toxicity to soil microorganisms has become imperative. This experiment was set up to study the effects of numerous insecticides on nitrification and ammonification in Arredondo fine sand.

Appleman and Sears (1) found no unfavorable results with 10 percent DDT on legume nodulation when soil treatments did not exceed 100 pounds per acre. Gainey (2) reported no overall detrimental effect from 100 pounds per acre of aldrin upon ammonification or nitrification. Jones (3) reported no effect from using a 50 percent wettable powder on nitrifying bacteria at concentrations of 0.001 and 0.01 percent; but at 0.1 percent and above, definite inhibition of the nitrifiers was evident. He also stated that concentrations of DDT of 0.1 percent and above had an inhibiting effect on the production of ammonia by soil microorganisms.

Morrison and Crowell (4) reported no effect from DDT on microorganisms when used at the rate of 10 pounds per acre. Smith and Wenzel (5) observed no definite injury to the nitrifiers when applied at the rate of 200 pounds per acre. They also stated that nitrifiers were not affected when chlordane and benzene hexachloride were used at rates of 100 pounds per acre; but at 500 pounds per acre of chlordane, the nitrate formers were definitely killed. Wilson and Choudhri (6) found no effects from DDT in concentrations of 5 percent on ammonifying and nitrifying bacteria.

MATERIAL AND METHODS

Experiments with DDT and Chlordane. Arredondo fine sand was selected for this experiment. A quantity of virgin soil was air-dried and screened. A 50 percent dust was added at 0, 15, 30, 60, and 120 parts per million. Each portion was mixed thoroughly and enough soil was removed to make ammonification studies. The soil was put in four-gallon pots and placed in the greenhouse, where the moisture was adjusted to 50 percent of the water-holding capacity.

Samples for nitrification studies were taken at the end of 7, 14, 21, 42, and 84 days and placed in quart Mason jars. These samples were mixed thoroughly and 30 mgm of N as ammonium sulfate was added to each 100 gram sample. They were incubated for four weeks at 28° C. Nitrates were determined by the phenoldisulfonic acid method.

Ammonification was determined by incubating duplicate samples of the treated soil for 14 days at 28° C. One gram of cottonseed meal and

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Florida Agricultural Experiment Station Journal Series, No. 147.

water equal to 50 percent of the water holding capacity were added prior to incubation. Ammonia was determined by extracting the soil with 10 percent NaCl and distilling the filtrate.

The experiments with chlordane were set up in a similar manner using a 50 percent wettable powder at 0, 25, 50, 100 and 200 pounds per acre.

Experiments with Aldrin. Because of difficulty encountered in maintaining satisfactory moisture levels in the above experiment, the procedure was changed to eliminate some of the error resulting from the uneven moisture content.

Arredondo fine sand was air-dried, screened and divided into five 20-pound portions. The soil was treated with a 2½ percent aldrin dust at rates of 0, 2, 4, 8, and 50 pounds per acre.

Each portion of soil was mixed in a rotary type mixer for one hour, after which 400 gram portions were placed in pint milk bottles. Five series were prepared in triplicate so that examinations could be made at the end of 7, 14, 21, 42, and 84 days of incubation.

Nitrification and ammonification were determined by the same methods that were used in the DDT and chlordane experiments.

RESULTS AND DISCUSSION

When DDT was used at 15, 30, 60, and 120 parts per million there was no significant effect on nitrification (Table 1).

TABLE 1.—EFFECTS OF DDT ON NITRIFICATION IN ARREDONDO FINE SAND.

Treatment	NO_3-N at Successive Days Following Treatment				
	7	14	21	42	84
ppm	ppm	ppm	ppm	ppm	ppm
None	71	224	198	228	63
15	120	240	218	195	88
30	75	250	195	105	75
60	96	195	87	218	85
120	33	210	158	220	78

DDT at the rates used in this experiment exhibited a stimulating effect on ammonification. The NH_3-N increased from 6.85 mgm. in the control to 10.95 mgm. in the treatment receiving 120 parts per million. These results are presented in Table 2.

No significant difference was noted in the amount of nitrates produced when chlordane was used at 25, 50, 100, and 200 pounds per acre, although nitrate production increased almost twofold between the 7 and 14-day samplings. These results are summarized in Table 3.

Ammonification was apparently stimulated by chlordane at the rates applied; however, the magnitude of the stimulation was much less than observed with DDT (Table 4).

Aldrin failed to produce any significant effects on nitrification or ammonification as shown in Table 5 and 6, respectively.

TABLE 2.—EFFECT OF DDT ON AMMONIFICATION IN ARREDONDO FINE SAND.

Treatment ppm	NH_3-N mgm./100 gm.
None	6.90
15	10.50
30	10.00
60	10.10
120	10.95

L.S.D. for treatment = 0.253 at 5% level;
= 0.429 at 1% level.

TABLE 3.—EFFECT OF CHLORDANE ON NITRIFICATION IN ARREDONDO FINE SAND.

Treatment	NO_3-N at Successive Days Following Treatment				
	7	14	21	42	84
ppm	ppm	ppm	ppm	ppm	ppm
None	152	264	232	223	224
12	104	244	214	199	161
25	108	255	237	276	189
50	112	270	237	215	172
100	135	242	223	188	230

TABLE 4.—EFFECT OF CHLORDANE ON AMMONIFICATION IN ARREDONDO FINE SAND.

Treatment ppm	NH_3-N mgm./100 gm.
None	5.70
12	6.30
25	6.65
50	6.20
100	5.50

TABLE 5.—EFFECT OF ALDRIN ON NITRIFICATION IN ARREDONDO FINE SAND.

Treatment	NO_3-N at Successive Days Following Treatment				
	7	14	21	42	84
ppm	ppm	ppm	ppm	ppm	ppm
None	252	196	255	272	297
1	272	190	298	292	257
2	264	185	257	282	301
4	250	178	277	278	289
25	255	178	270	263	252

TABLE 6.—EFFECT OF ALDRIN ON AMMONIFICATION IN ARREDONDO FINE SAND.

Treatment ppm	NH_3-N mgm./100 gm.
None	7.60
1	8.30
2	6.50
4	7.10
25	8.30

SUMMARY

No significant effect in nitrification was observed from DDT, chlordane and aldrin at rates used in this experiment.

DDT stimulated ammonification. No significant effect on ammonification was observed using chlordane; however, there was a trend which suggests a slight stimulation. Aldrin also showed no effect.

REFERENCES

1. Appleman, M. D., and Sears, O. H. 1946. Effects of DDT on Nodulation of Legumes. Jour. Amer. Soc. Agron. **38**: 545-550.
2. Gainey, P. L. 1952. Progress Report Commercial Project No. 100. (Unpublished Data.)
3. Jones, L. W. 1952. Stability of DDT and its Effects on Microbial Activities of Soils. Soil Sci. **73**: 237-241.
4. Morrison, H. E., and Crowell. H. H. 1951. Excerpt from Report entitled, "Results of 1951 Residual Soil Insecticide Investigations," Oregon Agricultural Experiment Station (Not for Publication).
5. Smith, N. R., and Wenzel, M. E. 1948. Soil Microorganisms are Affected by Some of the New Insecticides. Soil Sci. Soc. Amer. Proc. (1947) **12**: 227-233.
6. Wilson, J. K., and Choudhri, R. S. 1946. Effects of DDT on Certain Microbiological Processes in the Soil. Jour. Econ. Ent. **39**: 537-538.

THE EFFECT OF CERTAIN INSECTICIDES ON THE FLORA OF ARREDONDO FINE SAND

Granville C. Horn *

The effect of high concentrations of certain insecticides on the soil, as shown by retarded plant growth, is well known (8). With the advent of new organic insecticides such as DDT, Chlordane, and Aldrin, research workers and farmers have been concerned with the possible build-up of these insecticides to toxic levels. The change from the older standard insecticides to the more recent ones has come so rapidly that there has been limited time to actually determine the possible effects of their continued use.

Insecticides of the organic phosphates type decompose rapidly and it is improbable that a build-up of these would result. Others, especially DDT, are stable and repeated applications could result in a build-up that would not only be toxic to plants growing on the soil but also the microflora. Consequently, a series of experiments designed to study the effect of DDT, Chlordane, and Aldrin in Arredondo fine sand were conducted at Gainesville.

Ackley, Walter, and Bensen (1) reported that DDT accumulated rapidly in the surface soil the first two years of application, but thereafter, the accumulation rate decreased significantly.

Jones (4) found that concentrations of DDT increased the numbers of microorganisms growing on plates. After six months, five times as many organisms were growing on plates treated with 5000 pounds per acre of DDT as compared with untreated plates.

Jones also found that there was no correlation between plate counts and injury to a specific group of organisms such as ammonifiers, nitrifiers, or sulfur oxidizers.

Concentrations of DDT up to 100 pounds per acre had no unfavorable effect upon legume nodulation according to Appleman and Sears (2). However, nodules were more prominent in the untreated zone than in the treated zone. The height of the test plants was inversely proportional to the concentration of DDT used. Payne and Fults (5) stated that 103 pounds per acre of DDT reduced the numbers of nodules by one-half.

Wilson and Choudhri (9), using concentrations of DDT up to 5% noted no harmful effects on the total numbers of organisms, which include the ammonifying and nitrifying bacteria. Concentrations up to 2% had no effect upon nodulation.

DDT at concentrations up to 400 pounds per acre had no effect upon soil microorganisms according to Smith and Wenzel (7).

Simkover and Shenefelt (6), working with DDT, Chlordane, and BHC, observed that BHC greatly retarded mycelial growth of Rhizoctonia,

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TABLE 1.—Effects of DDT on the Numbers of Bacteria in Arredondo Fine Sand.

Treatment ppm	NUMBERS AT VARIOUS SAMPLINGS				
	7 days Millions/g.	14 days Millions/g.	21 days Millions/g.	42 days Millions/g.	L.S.D. for Treatment 2.38 at 5% 3.92 at 1%
0	.20	.92	6.54	7.26	3.73
15	.44	1.03	8.07	8.00	4.39
30	.46	1.50	10.80	13.74	6.63
60	.58	1.67	14.35	17.35	8.48
120	1.13	2.17	15.29	14.09	8.17
L.S.D. for Counts 1.16 at 5% 1.60 at 1%	.56	1.46	11.01	12.09	

TABLE 2.—Effects of DDT on the Numbers of Actinomycetes in Arredondo Fine Sand.

Treatment ppm	NUMBERS AT VARIOUS SAMPLINGS				
	7 days Millions/g.	14 days Millions/g.	21 days Millions/g.	42 days Millions/g.	L.S.D. for Treatment 4.45 at 5% 7.39 at 1%
0	.73	1.36	8.69	7.94	4.68
15	1.37	1.18	10.15	12.87	6.39
30	.92	1.47	15.05	15.02	8.12
60	.89	1.74	20.31	16.59	7.38
120	.98	1.43	23.85	24.75	12.75
L.S.D. for Counts 3.81 at 5% 5.24 at 1%	0.98	1.44	15.61	15.43	

TABLE 3.—Effect of DDT on the Numbers of Fungi in Arredondo Fine Sand.

Treatment ppm	NUMBERS AT VARIOUS SAMPLINGS				
	7 days Thousands/g.	14 days Thousands/g.	21 days Thousands/g.	42 days Thousands/g.	L.S.D. for Treatment 0.19 at 5% 0.32 at 1%
0	2.55	6.63	3.94	11.93	6.26
15	4.25	6.59	3.70	12.99	6.88
30	4.98	7.35	5.25	14.14	7.93
60	5.21	7.91	5.31	11.04	7.38
120	5.27	8.17	4.74	12.75	7.73
L.S.D. for Counts 0.638 at 5% 0.872 at 1%	4.45	7.33	4.59	12.57	

whereas DDT and Chlordane had no effect. They could find no effect of Chlordane or BHC upon nodulation of Black Locust Seedlings.

Gainey (3) reported no detrimental effect upon microbial numbers, protozoa, or Rhizobia from the use of aldrin.

EXPERIMENTAL PROCEDURE

The procedure followed in treating the soil with the various insecticides and sampling are described in a previous paper by Ross [1]. Bacteria, actinomycetes, and fungi were determined by the plate count method using egg albumen, glycerol and peptone-glucose agar, respectively.

RESULTS AND DISCUSSION

Data presented in Table 1 show that the numbers of bacteria increased significantly when 30 ppm of DDT was added to the soil, while rates of 60 and 120 ppm resulted in increases that were highly significant. However, at rates above 60 ppm there was a tendency for the numbers to level off or decline. There was a very significant increase in numbers of bacteria after the 7- and 14-day samplings. This increase was manifested in the control as well as in the treatments.

The number of actinomycetes was significantly increased where DDT was applied at rates of 60 and 120 ppm, Table 2. The trend was upward without reaching a maximum at any of the treatment levels used in this experiment. The numbers of actinomycetes did not vary significantly at any sampling date where no DDT was applied; however, when applied at 30 and 120 ppm, the numbers were significantly higher at 21 and 42 days following application than those found on the 7th and 14th days.

Data presented in Table 3 show the effects of DDT on the fungus population. It will be noted that the results are somewhat inconsistant in that 15, 30, and 120 ppm gave significant increases in numbers; whereas, 60 ppm significantly reduced the number of colonies appearing on the plates.

Chlordane-treated soil had a somewhat different microbial population from that found in the soil treated with DDT. Data in Table 4 show that Chlordane at all rates resulted in a significant increase in numbers of bacteria, while rates of 100 pounds per acre significantly reduced the numbers compared to those at the 50 pounds per acre rate. There was a progressive increase in numbers at 7, 14, and 21-days following treatment; however, at the 42nd day the numbers were significantly lower than at the previous sampling. It is important to note the interaction between treatment and sampling dates. There was a highly significant decrease in bacterial numbers at the 21 and 42 day samplings. The control at these dates decreased by a factor of approximatey three, at the same time the numbers increased approximately two-fold in the 200 pounds per acre treatment.

Although there was a trend toward increased numbers of actinomycetes in Chlordane-treated soils, as shown in Table 5, they are not statistically significant.

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[1] See paper by Harold F. Ross published elsewhere in these proceedings.

TABLE 4.—EFFECT OF CHLORDANE ON THE NUMBERS OF BACTERIA IN ARREDONDO FINE SAND.

Treatment #/A.	NUMBERS AT VARIOUS SAMPLINGS					
	7 days Millions/g.	14 days Millions/g.	21 days Millions/g.	42 days Millions/g.	84 days Millions/g.	L.S.D for Treatment 1.28 at 5% 2.13 at 1%
0	19.80	16.50	5.20	1.30	Missing Plot	10.70
25	12.70	15.10	18.70	2.40		12.23
50	12.80	17.55	25.30	2.90		14.64
100	11.25	13.10	25.30	2.60		13.06
200	12.20	16.40	25.30	2.60		14.13
L.S.D. for Counts 1.70 at 5% 2.36 at 1%	13.75	15.73	19.97	2.36		L.S.D for CxT 3.82 at 5% 5.30 at 1%

TABLE 5.—EFFECT OF CHLORDANE ON THE NUMBERS OF ACTINOMYCETES IN ARREDONDO FINE SAND

Treatment #/A.	NUMBERS AT VARIOUS SAMPLINGS					
	7 days Millions/g.	14 days Millions/g.	21 days Millions/g.	42 days Millions/g.	84 days Millions/g.	No. Significant Difference for Treatment
0	4.55	2.15	3.45	2.55	4.60	3.46
25	1.75	16.85	6.95	5.60	5.35	7.30
50	2.40	10.95	4.25	6.20	5.05	5.77
100	2.50	11.80	2.55	3.95	5.15	5.19
200	1.45	11.30	4.95	5.35	5.55	5.72
Counts Non Significant	2.53	10 61	4.43	4.73	5.14	

TABLE 6.—EFFECT OF CHLODANE ON THE NUMBERS OF FUNGI IN ARREDONDO FINE SAND

Treatment #/A.	NUMBERS AT VARIOUS SAMPLINGS					
	7 days Thous./g.	14 days Thous./g.	21 days Thous./g.	42 days Thous./g.	84 days Thous./g.	L.S.D. for Treatment 0.97 at 5% 1.62 at 1%
0	6.00	5.60	4.85	6.95	11.55	6.99
25	3.40	3.75	2.35	4.25	8.80	4.51
50	4.30	4.75	2.90	4.80	7.65	4.88
100	3.40	4.31	2.65	4.25	8.00	4.52
200	4.30	5.35	3.50	4.65	7.55	5.07
L.S.D. for Counts 0.77 at 5% 1.05 at 1%	4.28	4.75	3.25	4.98	8.71	

TABLE 7.—Effect of Aldrin on the Numbers of Bacteria in Arredondo Fine Sand

Treatment ppm	NUMBERS AT VARIOUS SAMPLINGS 7 days Millions/g.	14 days Millions/g.	21 days Millions/g.	42 days Millions/g.	84 days Millions/g.	No. Significant Difference for Treatment
0	2.57	.91	1.58	2 32	2.97	2.07
1	4.92	2.61	1.68	3.20	5.10	3.50
2	2.35	1.59	1.63	3.02	4.28	2.57
4	1.99	2.42	1.18	3.00	3.66	2.45
25	5.13	2.22	1.53	1.89	2.96	2.75
L.S.D. for Counts 0.65 at 5%	3.39	1.95	1 52	2.69	3.79	

TABLE 8.—Effect of Aldrin on the Numbers of Actinomycetes in Arredondo Fine Sand

Treatment ppm	NUMBERS AT VARIOUS SAMPLINGS 7 days Millions/g.	14 days Millions/g.	21 days Millions/g.	42 days Millions/g.	84 days Millions/g.	L.S.D. for Treatment 1.66 at 5% 2.34 at 1%
0	4.67	4.00	4.46	1.30	4.20	3.73
1	12.20	7.03	7.30	1.57	7.06	7.03
2	9.63	4.73	8.00	6.80	5.63	6.96
4	7.40	6.43	5.40	7.40	3.00	5.93
25	11.80	5.67	5.43	5.50	1.93	6.06
L.S.D. for Counts 1.53 at 5% 2.06 at 1%	9.14	5.57	6.53	4.51	4 36	

TABLE 9.—Effect of Aldrin on the Numbers of Fungi in Arredondo Fine Sand

Treatment ppm	NUMBERS AT VARIOUS SAMPLINGS 7 days Thous./g.	14 days Thous./g.	21 days Thous./g.	42 days Thous./g.	84 days Thous./g.	L.S.D. for Treatment 0.70 for 5% 1.04 for 1%
0	3.13	3.33	3.43	4 13	12.00	5.20
1	2.93	2.40	4.27	4.27	10 40	4.85
2	2.10	3.30	3.00	3.93	15.13	5.49
4	2.73	3.57	2.60	3.80	6.73	3.89
25	3.93	3.13	4.23	2.66	8 87	4.56
L.S.D. for Counts 0.97 at 5% 1.30 at 1%	2.96	3.15	3.51	3.76	10.59	

Chlordane proved to be highly toxic to the fungal population in the soil. Data in Table 6 show that treatment with Chlordane at all levels significantly reduced the number of colonies appearing on the plates.

Aldrin had no effect on the bacterial population, as may be seen upon examination of data in Table 7.

Contrary to results obtained in the case of bacterial numbers, it was found that aldrin stimulated actinomycete growth. There were increased numbers with 1, 2, 4, and 25 ppm of Aldrin, Table 8.

Soil treated with 4 ppm of Aldrin had significantly smaller numbers of fungi than were found when lighter dosages were used. There was a tendency toward increased numbers at the higher treatment level, back to the numbers recorded for the control. These data are recorded in Table 9.

SUMMARY

Additions of DDT to Arredondo fine sand resulted in significant increases in numbers of bacteria, actinomycetes, and fungi. However, the increases were not directly proportional to the amount of DDT added.

Additions of Chlordane up to 50 ppm increased the number of bacteria, reduced the number of fungi and had no significant effect on the actinomycete population.

Aldrin at rates of 25 ppm had no effect on the bacterial population in Arredondo fine sand, whereas 1, 2, 4 and 25 ppm significantly increased the numbers of actinomycetes. Aldrin seemed to have little effect on the number of fungi.

LITERATURE CITED

1. Ackley, W. B., Walker, K. C., and Bensen, M. R. 1950. DDT Residues in Orchard Soils, Proceedings of the Washington State Hort. Association, p. 85-88.

2. Appleman, M. D., and Sears, O. H. 1946. Effect of DDT on Nodulation of Legumes, Journal of the American Soc. of Agronomy, 38: 545-550.

3. Gainey. 1952. Progress Report, Commercial Project No. 100, March, Department of Bacteriology, Kansas Agri. Expt. Sta.

4. Jones, L. W. 1952. Stability of DDT and its Effect on Microbial Activities, Soil Science 73: 237-241.

5. Payne, M. G., and Fults, J. L. 1949. Some Effects of 2, 4-D, DDT, and Colorado 9 on Root Nodulation in the Common Bean. Journal of the American Soc. of Agronomy 39: 52-53.

6. Simkover, H. G., and Shenefelt, R. D. 1951. The Effect of BHC and Chlordane on Certain Soil Organisms, Journal of Economic Entomology, 44: 426.

7. Smith, N. R, and Wenzel, M. E. 1947. Soil Microorganisms are Affected by Some of the New Insecticides, Soil Sci. Soc. Am. Proceedings, 12: 227-233.

8. Wilson, J. D., and Sleesman, J. P. 1948. The Influence of Various Pesticides on the Growth and Transpiration of Cucumber, Tomato, and Potato Plants. Ohio Agri. Expt. Sta. Bulletin 676.

9. Wilson, J. K., and Choudhri, R. S. 1946. Effects of DDT on Certain Microbiological Processes in the Soil, Journal of Economic Entomology, 39: 537-538.

SOME EFFECTS OF D-D, EDB AND CHLOROPICRIN ON MICROBIOLOGICAL ACTION IN SEVERAL FLORIDA SOILS

Geo. D. Thornton*

When a toxicant of any kind is used to control certain undesirable organisms in the soil, it immediately becomes important to know its effect on other organisms of a beneficial nature. The purpose of this paper is to report findngs [1] of this kind when D-D, EDB and chloropicrin were used to fumigate field soils as a measure of control against nematodes. The work has been largely cooperative between the Soils Department, Main Station, Gainesville; the Central Florida Station, Sanford; and the Horticulture Department, Main Station, Gainesville.

EXPERIMENTS WITH D-D AND EDB ON LEON FINE SAND AT THE CENTRAL FLORIDA STATION, SANFORD

A field experiment [2] was set up on Leon fine sand at the Central Florida Experiment Station where D-D and EDB were used at rates of 23 and 46 gallons per acre. Soil samples were taken seven days after treatment and at successive seven-day intervals until further sampling was deemed unprofitable. The samples were shipped by Railway Express the same day they were taken. They arrived in Gainesville the following morning, where they were used in respiration, ammonification and nitrification studies.

TABLE 1.—Effect of Fumigation on Carbon Dioxide Evolution from Leon Fine Sand, Sanford, 1948

Treatment	Mgms. Carbon Dioxide Released per 200 Grams Soil During 40 Hours of Incubation			
	7 Days After Treatment*	14 Days After Treatment	21 Days After Treatment	28 Days After Treatment
1. 46 gal. D-D per A.	12.2	17.8	28.4	37.2
2. 23 gal. D-D per A.	14.5	24.7	29.4	49.8
3. 46 gal. EDB per A.	13.4	24.3	18.4	29.4
4. 23 gal. EDB per A.	14.6	20.1	16.7	31.8
5. Control	13.1	18.2	23.9	27.8

* Incubated 24 hours.

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[1] Some Effects of Dichloropropane-Dichloropropene (D-D), Ethylene Dibromide (EDB) and Chloropicrin on the Activities of Certain Groups of Soil Organisms. A thesis presented to the Graduate Council of the University of Florida by Leonard C. Smith.

[2] Dr. J. R. Christie, Senior Nematologist, U.S.D.A., is given credit for furnishing soil samples from this field experiment.

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Respiration in the variously treated soils was studied by measuring the evolution of carbon dioxide during a 40-hour incubation period with mannitol as the energy source. Although the data, shown in Table 1, are not statistically significant, there was a tendency for release of more carbon dioxide from the treated soils than from the control.

There was no difference in the rate of ammonia production from cottonseed meal in the variously treated soils. This indicated a quick recovery of the general floral population or a failure of the fumigants to effect certain groups of vigorously growing organisms.

The effect of fumigation on subsequent nitrate production was quite different from that observed in the cases of respiration and ammonification. With only two exceptions, there was a significant reduction in nitrate production at all sampling dates when D-D was used at either 23 or 46 gallons per acre. Table 2. A reduction in nitrates was noted in the samples from the EDB treated plots at the fifth, sixth and seventh samplings. Samples taken the twelfth week following application of the fumigants failed to show any variation in nitrate production contributable to any treatment.

TABLE 2.—Effect of Fumigation on Subsequent Nitrate Production in Leon Fine Sand. Sanford, 1948-49

Treatment		Nitrate — N at Various Sampling Dates						
		Oct. 18	Oct. 25	Nov. 1	Nov. 8	Nov. 15	Nov. 22	Nov. 29
		ppm	ppm	ppm	ppm	ppm	ppm	ppm
D-D, 46 gal. per A.		53	250	50	43	56	50	56
D-D, 23 gal. per A.		100	140	93	76	163	113	160
EDB, 46 gal. per A.		246	216	146	210	240	133	146
EDB, 23 gal. per A.		293	310	136	213	290	183	206
Check		250	299	163	273	440	200	273
Min. needed for significance	.05	32	......	......	96	126	24	25
	.01	......	.....	.....	..	...	36	......

300 ppm N as ammonium sulfate added to 100 gms. soil and incubated at room temperature for 28 days.

Treatment was repeated on these same plots the following year. Beginning two weeks after treatment and continuing at weekly intervals for six weeks, samples were taken and shipped to Gainesville for use in nitrification studies. Extensive rains fell between the time of application and the first sampling; consequently, only D-D applied at the heavy rate gave any significant reduction in nitrate production.

EXPERIMENTS WITH D-D, EDB AND CHLOROPICRIN ON ARREDONDO FINE SAND AT GAINESVILLE

The Horticulture Department, Florida Agricultural Experiment Station, Gainesville, gave permission to sample plots treated with D-D, EDB and chloropicrin at the rate of 30 gallons per acre. Samples were taken ten days after treatment and at successive ten-day intervals for 60 days and used in nitrification studies. The results are given in

TABLE 3.—EFFECTS OF FUMIGATION ON SUBSEQUENT NITRATE PRODUCTION IN ARREDONDO FINE SANDY LOAM. GAINESVILLE, 1949

Treatment	Nitrate — N Production in Soils Taken at Intervals Following Treatment					
	10 Days	20 Days	30 Days	40 Days	50 Days	60 Days
	ppm	ppm	ppm	ppm	ppm	ppm
D-D, 30 gal. per A.	10	15	22	25	38	27
EDB, 30 gal. per A.	32	37	38	32	50	34
Chloropicrin, 30 gal. per A.	27	45	53	50	54	55
Check	38	40	48	51	59	43
Min. needed for significance .05	3	5	5	3	2	2
.01	....	....	....	5	3	3

Table 3 where it will be noted that nitrate production was significantly reduced by chloropicrin at the ten-day sampling and again at the 50-day sampling. The D-D and EDB treated soils had a significant reduction in nitrate production at all sampling dates except at the 20-day sampling in the case of the EDB treated soil.

TABLE 4.—EFFECT OF D-D WHEN APPLIED TO SOILS AT VARIOUS TEMPERATURES ON SUBSEQUENT NITRIFICATION. GAINESVILLE

Treatment		Nitrate — N Production	
Temperature	Fumigation	1st Sampling*	2nd Sampling**
		ppm	ppm
0°F.	None	280	260
0°F.	D-D	60	120
35°F.	None	230	250
35°F.	D-D	110	100
46°F.	None	190	190
46°F.	D-D	100	70
52°F.	None	260	220
52°F.	D-D	80	120
Greenhouse	None	210	210
Greenhouse	D-D	90	90

* Samples were taken 24 hours after removing soils from controlled Temperature storage. 300 ppm Nitrate-N added as ammonium sulfate and incubated for 21 days at 82° F. (28° C.).

** Samples were taken 7 days after removing from controlled Temperature storage. 300 ppm Nitrate-N added as ammonium sulfate and incubated 21 days at 82° F. (28° C.).

EFFECT OF SOIL TEMPERATURE ON THE VOLATILIZATION OF D-D AND SUBSEQUENT EFFECT ON NITRIFICATION

Thirty one-gallon pots were filled with Leon fine sand to be treated and stored at the following temperatures: 0°F., 35°F., 46°F., 52°F., and 60° to 80°F. Six pots were stored at each of the above temperatures

for 48 hours, after which the soil in three pots was treated with D-D at the rate of 3 cc. per square foot of surface area. The pots then remained in storage for ten days after which they were removed to the greenhouse benches. On the 11th and 18th days following treatment, samples were taken for nitrification studies in the laboratory. Two celery plants were transplanted to each pot one day after removal from storage.

The results of the nitrification studies are given in Table 4, where it is noted that the D-D treatment had significantly reduced the nitrate production in all cases.

There was no significant difference in the weights of the celery plants from the variously treated soils when the experiment was terminated five weeks after transplanting. However, plants in soils treated with D-D and stored at 0°F. and 35°F. were smaller and light green in color when compared with the plants receiving other treatments. At harvest, the roots of these plants were brownish in appearance indicating injury resulting from the apparent slow volatilization of the D-D at temperatures of 35°F. or lower.

DISCUSSION

In general, the results reported here with respect to ammonification and nitrification are in agreement with those reported by Spencer and Jack (2) who worked with Manatee fine sandy loam and Leon fine sand in the Bradenton area and by Martin (1) in California. In most cases an accumulation of ammonia and a reduction in nitrates was noted. The extent of these changes was dependent upon the material used and the rate of application. D-D was found to be most toxic and depressed nitrification for the longest period, while EDB and chloropicrin were toxic in lesser degrees.

Respiration studies were of little value in studying the effects of fumigants on the soil population. The reason for this was the very rapid recovery of certain original species or the establishment of new introductions. Martin (1) found that in certain treated pots of soil, the fungus species which first became the dominant types remained dominant for the rest of the experiment. In other treated pots, a succession of forms occurred. This same thing often occurred in replicate pots of the same treatment.

The temperature of the soil at the time of, and immediately following, treatment with D-D had little effect on subsequent nitrate production. However, the appearance of the roots of celery plants transplanted in D-D treated soils ten days after treatment and 24 hours after removal from controlled temperature storage gave indication that the rate of volatilization was reduced at temperatures of 35°F. or lower.

LITERATURE CITED

1. Martin, James P. Effects of Fumigation and Other Soil Treatments in the Greenhouse on the Fungus Population of Old Citrus Soil. Soil Science **69**: 107-122. 1950.

2. Spencer, Ernest L., and Amegda Jack. Nitrogen Transformation in Seedbeds as Affected by Nematocidal Treatment. Proc. Fla. Sta. Hort. Society **63**: 125. 1950.

CROP RESPONSE AS INFLUENCED BY SOIL FUMIGATION

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From the papers already presented on this Symposium it should be apparent to each of us that considerable work has been carried out in Florida on the control of soil-borne pests, both diseases and insects. Much of this work, however, has been centered on the control of the root-knot nematode. These parasitic nematodes not only attack cultivated crops such as tobacco, vegetables, ornamentals, and trees, but also damage certain legumes used as cover crops. The pests are found in all of our sand lands, the muck soils of the Everglades and the marl soils of South Florida. The control problem is now further complicated by the recent identification here in Florida of two externally feeding parasitic nematodes, the sting nematode (*Belonolaimus* sp.) and the stubby-root nematode (*Trichodorus* sp.).

In any discussion of soil fumigation as a means of controlling soil-borne diseases and other plant pests it must be recognized that such control methods drastically disturb the normal soil processes, in that many beneficial soil organisms are destroyed along with the parasitic pests. It is often a question whether or not fumigation may sometimes do more harm than good. Not only does fumigation upset the normal balance of organisms in the soil but there is always the possibility that the fumigant may leave a residue in the soil which in time may become toxic after repeated applications.

EMPHASIS ON NEMATODES

With this as a background, let us review briefly some of the early work which has been done here in Florida with soil fumigants on vegetable crops. In this report I wish to focus your attention on fumigation not as it controls soil-borne parasites but rather as it affects the crop itself. I appreciate only too well that if fumigation increases crop yield it does so primarily by restricting the factors competing with the plant in the soil. Moreover, because of the volume of reports of studies published on the effect of fumigation as a fungicide, as a herbicide, and as a nematocide, I will limit my discussion to fumigation as a nematocide.

It is obvious that no control method will protect a crop in the field if nematodes are introduced on the roots of transplants. Therefore, every precaution possible should be taken to achieve perfect control of nematodes in the seedbed. Most seedbed studies to date deal with the control of soil-borne diseases and parasites by soil fumigation. Thus, there are only limited data on crop response in seedbeds as measured by size and number of transplants. Seedbed studies, initiated in Bradenton in 1945, have shown that plots fumigated with methyl bro-

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Florida Agricultural Experiment Station Journal Series, No. 140.

mide, aero cyanate, and allyl alcohol yielded more plants suitable for transplanting than the non-fumigated plots (1). Although all three of these fumigants proved effective in controlling post-emergence damping-off and reduced the amount of root knot, only methyl bromide prevented the development of root knot.

Experimental soil fumigation in the field in Florida dates back to the spring of 1945 when Tisdale, Brooks, and Harrison (10) tested snap beans, lima beans, squash, and tomato using DD, chlorpicrin and calcium cyanamid. Chlorpicrin increased yields significantly with lima beans and tomato, but DD increased yields only with lima beans. Calcium cyanamid stunted all crops and produced tip-burn on tomatoes, snap beans and lima beans, which indicated that the material may be slow in breaking down. In the spring of 1946 Jamison, Nettles, and Janes (3) observed that Larvacide and Dowfume W-10 increased the yield of cucumbers.

Since this early work, considerable attention has been given to fumigation for nematode control, especially with DD and EDB. Some of these tests have yielded conflicting results, as might be expected, since it is now known that tests even in the same area may vary from year to year, depending on rainfall and other environmental and weather conditions.

In general, the tests with DD may be summarized as follows: Tomato yields were increased on marl soil (15) and on some sand land such as Manatee fine sandy loam (12), but not on Bradenton fine sand (9). On Arredondo fine sand Nettles and Myers (4) observed a severe rolling of tomato leaves occurring about the time the first flower cluster set fruit. This condition was associated with above-normal amounts of ammoniacal nitrogen in the soil. Volk (11) subsequently concluded that a similar nutritional leaf roll of potato is caused by a deficiency of the nitrate form of nitrogen in the presence of adequate nitrogen in other forms or under conditions in which nitrate nitrogen is depleted early in the growing period. Observations published in 1950 (7) show that the low nitrate-nitrogen values and high ammoniacal-nitrogen values generally observed following soil fumigation seem to be due to the detrimental action of fumigating chemicals on the nitrifying organisms in the soil. As regards other crops, DD seemed to be harmful to peas (14) and squash (8) but with beans (6) increased yields were obtained. It had no effect on potatoes on the marl soils of southern Florida (2).

The reports on EDB are quite similar to those observed with DD. Some growth retardation of tomato has been reported with EDB during wet weather (12). At Sanford (14) EDB was not injurious on peas, as was the case when DD was used, but even EDB did not prove beneficial. Some yield increases were obtained at Bradenton (12) with tomatoes and at Gainesville (5) with cucumbers. Other tests with potatoes at Homestead (2), squash at Bradenton (13), and beans and sweet potatoes at Gainesville (6) were inconclusive.

Several tests (9) have been carried out with calcium cyanamid and CBP-55, an emulsifiable chloro-bromo-propene, but the results to date have also been inconclusive. Recent preliminary tests using methyl bromide on a field scale indicate that this material may have possibilities.

Many studies have pointed out that plants will be stunted or permanently injured if set out in a field too soon after it has been fumigated. The reason for this is simple. In order for a chemical to be effective as a fumigant, it must have certain toxic properties. Thus, after the fumigating action has been completed, the concentration of the chemical must decrease to the point where it will not injure the plant. With some fumigants only a day or two is required but with others a waiting period up to four weeks is recommended. Soil moisture and aeration are important factors in determining the time required for the dissipation of the fumigant to the point where it will not injure plant growth.

It is apparent from the conflicting results reported above that it is questionable whether or not we should advise the grower to fumigate if we use yield data as a criterion of fumigant effectiveness. However, a critical analysis of the data reveals that under Florida conditions fumigation does seem to give important yield increases at times, especially during the spring crop season. This is the season when we might expect nematodes to be most active because temperatures are higher and usually rainfall is less.

In the past we have been hesitant about recommending chemical fumigation except as a last resort. This reasoning was based on the fact that it had been observed repeatedly that full-scale treatment controls nematodes on the first crop following fumigation but the second crop in those areas suffers more severe damage than in similar non-fumigated areas. The expense of full-scale treatment before each crop is prohibitive for most growers.

At present we are recommending, however, the so-called "in-the-row" fumigation in areas where nematodes are a problem. As Walter and Kelsheimer pointed out in 1949 (12), no fumigant on a field scale, regardless of method of application, will probably be completely effective in preventing the development of root knot on a susceptible crop that remains in the field for as long as three months. The longer the life of the plant, the greater is the need for protection against infestation.

Most growers and technical workers now believe that the major share of reduction in yields of vegetable crops is due to the effect of the nematodes on seedlings during the first month or so in the field. During this early growth period the radial spread of root growth would not exceed the radius of effectiveness demonstrated for "spot" applications of the soil fumigants. Thus, in-the-row treatment should effectively fumigate this area of seedling root growth. Compared with overall treatment, this in-the-row treatment not only reduces the cost of fumigant required per acre by 75 or 80 percent but it also minimizes any possible accumulation of harmful chemical residues in the soil.

At the Gulf Coast Station we apply the fumigant at the same time we fertilize and bed up, thereby eliminating the labor cost of separate fumigation. It should be emphasized that with in-the-row treatment, any operation which might throw non-treated soil from the middles to the treated beds should be delayed as long as possible.

In closing, let me summarize briefly our thinking concerning soil fumigation as it pertains to vegetable production.

1. When deemed advisable, in-the-row fumigation can be good insurance. It will give the seedling an opportunity to become established

and produce a good root system. With such a start it should be able to keep ahead of any subsequent root-knot infestation unless growth is retarded by some unfavorable weather or environmental conditions.

2. Certain of the newer fumigants seem to have definite fungicidal and herbicidal properties which may influence some subsequent cultural practices in the management of the crop.

3. We still do not know whether repeated fumigation before each crop will eventually build up in the soil toxic residues which in turn might affect the quality of the product raised. The danger of such a possible build-up, however, is minimized by in-the-row fumigation as compared with the overall treatment.

4. More research is needed on the management of fumigated areas. These studies should eventually give definite answers to such questions as:

(a) How long should the grower wait after fumigation before seeding or transplanting?

(b) What effect does soil moisture and aeration have on this waiting period?

(c) How important is soil reaction on the effectiveness of fumigation?

(d) Should our ideas on fertilization be re-evaluated if fumigation is practiced?

LITERATURE CITED

1. Burgis, D. S., and Amegda Jack. Florida Agri. Expt. Stat. Annual Report **1952**: 253-255.

2. Conover, R. A., and D. O. Wolfenbarger. Florida Agri. Expt. Stat. Annual Report **1950**: 249.

3. Jamison, F. S., V. F. Nettles and B. E. Janes. Florida Agri. Expt. Stat. Annual Report **1946**: 68-69.

4. Nettles, V. F., and F. E. Myers. Florida Agri. Expt. Stat. Annual Report **1949**: 99-100.

5. Nettles, V. F. Florida Agri. Expt. Stat. Annual Report **1951**: 84.

6. Nettles, V. F. Florida Agri. Expt. Stat. Annual Report **1952**: 98-99.

7. Spencer, E. L., and Amegda Jack. Nitrogen transformation in seedbeds as affected by nematocidal treatment. Proceedings, Fla. State Horticultural Society **63**: 125-128, 1950.

8. Spencer, E. L., Amegda Jack and W. G. Cowperthwaite. Florida Agri. Expt. Stat. Annual Report **1951**: 221.

9. Spencer, E. L., Amegda Jack and W. G. Cowperthwaite. Florida Agri. Expt. Stat. Annual Report **1952**: 247-248.

10. Tisdale, W. B., A. N. Brooks and A. L. Harrison. Florida Agri. Expt. Stat. Annual Report **1945**: 91-95.

11. Volk, G. M. Florida Agri. Expt. Stat. Annual Report **1951**: 109-110.

12. Walter, J. M., and E. G. Kelsheimer. In-the-row application of soil fumigants for vegetables on sandy soil. Proceedings, Florida State Horticultural Society **62**: 122-126, 1949.

13. Walter, J. M., E. G. Kelsheimer and E. L. Spencer. Florida Agri. Expt. Stat. Annual Report **1949**: 131-132.

14. Wilson, J. W., and J. R. Christie. Florida Agri. Expt. Stat. Annual Report **1949**: 176-177.

15. Wolfenbarger, D. O. Florida Agri. Expt. Stat. Annual Report **1952**: 283-285.

THE BENEFITS OF FLOODING IN THE CONRTOL OF NEMATODES

WALTER H. THAMES, JR.*

In view of the decision of the author to publish his preliminary report on the above subject in the *Plant Disease Reporter* it will be reviewed here only in abstract form.

His review of the literature with reference to the efficacy of land flooding for the control of root-knot nematodes (*Meloidogyne* spp.) might be summarized by stating that while short periods of flooding greatly reduced active infestation by this organism of the sensitive crops that followed, much longer periods were necessary to produce anything like "eradication", i.e., 12 to 22 months as on the peat soils of King Island near Stockton, California. This is particularly on account of the high resistance of the egg forms to such treatment.

Roots of first crop of celery showing influence of prior flooding of the land (in connection with rice culture) on root-knot infestation. Left—from flooded area. Right—from unflooded area.

The principal research work reported on pertained to residual benefits that appeared in the way of root-knot control in sensitive truck crops that followed the routine flooding required for rice production under Everglades conditions (peat soils). This involved a comparison of the incidence of root knot on celery grown on unflooded land that had been dry-cultured to rice to that growing on soil that had experienced paddy conditions through a normal period of rice growth. The results on the first crop that followed are well shown on the roots of celery plants of the small scale figure shown here.

While a second crop, beans, on these same areas still showed a considerable diminution of infestation in the plants grown on the formerly flooded area, the third crop, celery, showed that these protective benefits largely had disappeared, by the time the plants were harvested. This, however, was nearly two years after the close of the flood period and the preparation of the plots for their first cropping.

According to the observations made on the first and second plantings following flooding, this operation that is of necessity carried on in conjunction with rice culture should be very helpful in the control of root-

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knot on highly susceptible vegetable crops that follow the harvesting of the rice crop, at least within a period of twelve to fourteen months.

The discussion emphasized the considerable amount of important investigational work that remains to be done for the full evaluation of such practices as flooding and crop rotation, including the use of resistant crops, of course, wherever possible, for the control of rootknot as well as several other forms of equally vicious, soil-inhabiting nematodes.

EFFECTS OF TWO-YEAR ROTATIONS ON NEMATODE DISEASES, YIELD, AND QUALITY OF CIGAR-WRAPPER TOBACCO

Randall R. Kincaid *

Cigar-wrapper (shade) tobacco in Florida is grown in short rotations with various other crops or, less commonly, for several years in succession. Incidence of soil-borne diseases and fertility of the soil, as affecting yield and quality of tobacco crop, are important factors in determining the length and composition of the rotation.

Some of the pertinent literature on tobacco rotations is reviewed here. Two-year rotation studies on cigar-wrapper tobacco, made at the North Florida Experiment Station, with particular reference to nematode diseases, yield, and quality of the cigar-wrapper tobacco crop, are presented.

REVIEW OF LITERATURE

Lunn and others (9)[1] studied the effects of bare and natural weed fallow and pure stands of certain weeds on the tobacco crops following. On Maryland tobacco in 2- or 3-year rotations, bare fallow gave declining yields and value per pound, as compared with natural weed fallow. Ragweed (*Ambrosia artemisiifolia* L.) and horseweed (*Erigeron canadensis* L.) gave higher crop values than natural weed fallow, especially when the weeds were turned under in spring rather than in fall. A vegetation cover over winter was considered necessary to favorable results. Lambsquarters (*Chenopodium album* L.) and Kobe lespedeza were among the least favorable species, producing in tobacco "symptoms . . . associated with brown root rot." On flue-cured tobacco in South Carolina also ragweed and horseweed gave better results than natural weed fallow, and lambsquarters gave poor results. The investigators stated that nematodes often were the most apparent cause for failure of the tobacco plants to grow. This remark apparently had reference to root-knot nematodes.

Graham (4) found that flue-cured tobacco following cotton or corn suffered more from nematode root rot (*Pratylenchus zeae* Steiner and *P. leiocephalus* Steiner) than tobacco following peanuts, oats and weeds, or tobacco.

Valleau and associates (15) recommended that tobacco follow weeds, rather than bluegrass, corn, soybeans, timothy, or orchard grass in order to control brown root rot. Diseased roots of tobacco and the unfavorable rotation crops were found (14) to harbor numerous parasitic nematodes, which were classified as meadow nematodes. Certain weed species were also found infested, but ragweed yielded only an occasional specimen. Continuous cropping with tobacco, with cover crops of a small grain or hairy vetch, was also found favorable to brown root-rot control (15).

* The assistance of A. L. Taylor with nematode studies, and of the late Messrs. J. D. Warner and Jesse Reeves with agronomic phases is hereby gratefully acknowledged.

[1] Figures in parentheses refer to Literature Cited.

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Clayton and others (3) recommended for root-knot control that crops preceding flue-cured tobacco should be peanuts, crotalaria, weeds, oats, or rye. Preceding these in a 3-year rotation, less resistant crops, such as cotton, corn, or Brabham or Iron cowpeas, might be grown.

Anderson (1) stated that in Connecticut continuous cropping of tobacco year after year on the same land is considered better practice than rotation. The growing of tobacco following hay, corn, or forage crops should be avoided because of the danger of brown root rot, attributed to meadow nematodes (2).

Kincaid and Reeves (8) reported that bare fallow for 6 months following each annual crop of cigar-wrapper tobacco gave steadily declining yields, as compared with 3 months' fallow followed by a cover crop of oats. There was no difference in the incidence of root knot with these practices. Native vegetation, consisting mainly of goose grass (*Eleusine indica* Gaertn.), crab grass (*Digitaria* sp.), and jungle rice (*Echinochloa colona* Link.), gave significantly reduced yield and a severe root rot. It was characterized by more or less complete disappearance of lateral roots and enlargement of the remaining roots, and was later called "coarse root." Steiner (12) found that roots having this type of injury were attacked by the smooth-headed meadow nematode, and stated that the condition "might very well be conditioned by meadow nematodes." The writer in unpublished data also found meadow nematodes in connection with coarse root, both in the tobacco roots and in adhering soil, and Taylor (13a) found them in lesions on the enlarged roots.

Root knot and coarse root are a constant menace to the cigar-wrapper tobacco crop. Kincaid and Volk (6) reported that soil treatment with nematocidal fumigants controlled root knot well in most tests, but controlled coarse root poorly. Although soil fumigation is now a common practice, they (7) considered that it should be used in conjunction with suitable rotations to provide the best possible conditions for producing high yield and good quality.

EXPERIMENTAL

Six test crops of cigar-wrapper tobacco were grown in ten different rotations, with continuous tobacco as the check. Two sets of duplicate plots were used. Each year one set was grown to shade tobacco and the other to the various rotation crops. These crops, grown during the 18-month period between crops of tobacco, were as follows:

Summer legumes and oats;

- *Crotalaria spectabilis* (Roth), oats for hay, crotalaria
- Velvet beans, oats for hay, velvet beans
- Cowpeas (Brabham or Iron), oats for hay, cowpeas

Native vegetation, corn with native vegetation;

Native weeds and grasses [2] in fall and again in summer;

- Beggarweed (*Meibomia purpurea* Vail.)
- Cocklebur (*Xanthium pungens* Wallr.) (Fig. 1)
- Coffeeweed (*Emelista tora* B. and R.)
- Texas millet (*Panicum texanum* Buckl.)

[2] Cocklebur was identified by S. F. Blake, others by Erdman West.

Crab grass (*Digitaria serotina* Scop.)
Goose grass (*Eleusine indica* Gaertn.)

Continuous cropping with tobacco (check), followed each year by clean fallow and oats for green manure

The three weeds and three grasses included were those found in a survey of commercial shades to be the most common species. Each of these, except goose grass, was predominant in certain shades.

An attempt was made to maintain the crops except corn in pure stands. This was accomplished fairly well, except for the grasses, which were difficult to recognize and rogue in the seedling stage, and beggarweed, which was difficult to grow under the conditions of the test. Composition of stands was estimated and green weight was determined at approximately the time of maximum growth.

Fig. 1.—Cockleburs grown in 2-year rotation experiment with cigar-wrapper (shade) tobacco. Shade frame had not yet been constructed.

Tobacco was grown, harvested, cured, sweated, and graded according to current commercial practices (5). Stable manure and commercial fertilizer were applied for each test crop of tobacco. Tobacco in alternate years of the continuous tobacco cropping check was fertilized with commercial fertilizer only and grown without shade.

Incidence of root knot and coarse root was determined by examining the roots of a suitable sample of plants from each plot shortly after the end of leaf harvest, rating them according to the severity of each disease, and calculating indexes based on 100. Yield was determined by weigh-

ing the leaves after sweating. Grade index was a measure of the value of the leaves per pound. Crop index, obtained by multiplying yield by grade index, was a measure of the value of the crop. Burn test was made by the strip method, and the results by primings were averaged. The approximate agronomic rank of the eleven treatments was determined primarily by the crop index, modified in a few instances by the burn test or the practicability of the rotation.

Results for the six test crops of cigar-wrapper tobacco, 1944 to 1949, inclusive, were averaged and reported in Table 1. In the comments which follow, the rotations are considered in the order of their agronomic rank. Yield, grade, and burn are mentioned only where they are comparatively high or low.

TABLE 1.—Six-Year Average Results of Cigar-Wrapper Tobacco Crops Grown in Two-Year Rotations, 1944-1949.

Rotation Crops	Root Knot Index	Coarse Root Index	Yield Lbs./A.	Grade Index	Crop Index	Burn Test Sec.	Approx. Agronomic Rank
Crotalaria and oats	9	29	1,282	.645	830	9.6	10
Valvet beans and oats	15	59	1,302	.666	866	10.2	7
Cowpeas and oats	10	45	1,273	.668	851	9.8	8
Corn and native spp.	26	42	1,332	.677	905	11.0	3
Beggarweed	7	43	1,292	.671	867	10.6	6
Cocklebur	21	31	1,340	.675	902	10.9	1
Coffeeweed	5	51	1,236	.674	836	10.2	9
Texas millet	7	43	1,376	.675	928	10.4	2
Crab grass	16	44	1,329	.657	873	10.3	5
Goose grass	45	49	1,258	.652	820	10.6	11
Tobacco, continuous	34	37	1,280	.672	863	11.4	4
L. S. D., 5%	18	10	114	.029	97	1.3	

1. Cocklebur. Root knot medium, coarse root low; yield second only to Texas millet; grade and burn high.[3] This rotation was becoming lower in rank as the experiment progressed.

2. Texas Millet, locally called "buffalo grass." Root knot very low; coarse root medium; yield slightly higher than cocklebur; grade high. This rotation was more expensive to operate than cocklebur, because of heavy cultivation required to incorporate the grass into the soil, but with improved methods of handling it would probably rank first. This rotation was becoming higher in rank as the experiment progressed.

3. Corn and Native Vegetation. Root knot and coarse root medium. Comparative disease indexes decreased and yield increased as cockleburs gradually dominated the native vegetation in the corn. Corn yields averaged 54 bushels per acre.

4. Continuous Tobacco. Root knot medium; coarse root low; grade

and burn high. If blackshank had been an important factor, continuous tobacco would have had a lower rank.[3]

5. CRAB GRASS. Root knot low; coarse root medium; yield high. This grass was also difficult to incorporate into the soil.

6. BEGGARWEED. Root knot very low; coarse root medium. Results with this rotation were questionable because of beggarweed crop failures.

7. VELVET BEANS AND OATS. Root knot low; coarse root very high.

8. COWPEAS AND OATS. Root knot low; coarse root medium; burn low.

9. COFFEEWEED. Root knot very low; coarse root high; yield low; grade high. Coffeeweed decomposed slowly in the soil.

10. CROTALARIA AND OATS. Root knot and coarse root low; grade and burn low. This rotation might have given better results with lower rates of fertilization.

11. GOOSE GRASS. Root knot and coarse root high; yield and grade low.

Green weight of cover crops grown twice in each 2-year cycle of the cocklebur, Texas millet, and corn-native vegetation rotations averaged 9 to 10 tons per acre. Green weight of oats for green manure grown each year in the continuous tobacco treatment averaged $4\frac{1}{2}$ tons.

Coefficient of correlation between root-knot index and yield was $-.12 \pm .20$; between coarse root index and yield, $-.26 \pm .19$. Although the latter was the higher, neither approached significane.

DISCUSSION

Native weeds and grasses gave widely different rank. They differed greatly in nematode disease indexes, yield and quality of the tobacco crop and in their practicability.

Cocklebur grew readily as a volunteer crop, starting in May to July, made high green weight yields, and was readily harrowed and rapidly decomposed, leaving the soil in good physical condition. Texas millet was less readily harrowed and more slowly decomposed but gave excellent tobacco crop response.

Some information was obtained regarding nematodes attacking cocklebur. Steiner (11) reported that cocklebur roots from the test plots "harbored quite a number of different species of nematodes but none that we consider parasitic." In another sample, he found *Aphelenchoides* sp. as reported by Tarjan (13). The writer found in still other collections meadow nematodes in cocklebur roots and adhering soil.

Steiner (10) also examined roots of tomato grown as an indicator crop in soil from rotation plots. He found meadow nematodes in connection with cocklebur, Texas millet, and cowpea rotations, and kidney-shaped nematodes (*Rotylenchus reniformis*) in connection with cocklebur, beggarweed, and coffeeweed rotations. Root-knot nematodes were also present in several samples.

The lack of significant correlation between disease indexes and yield suggested that yield was affected by other factors, probably including

[3] Blackshank (*Phytophthora parasitica* var. *nicotianae*) occurred in 1945 in cocklebur, goose grass, and continuous tobacco plots; in 1949 (in order of decreasing severity) in cocklebur, corn, continuous tobacco, Texas millet, and goose grass plots. No conclusions are warranted, however, from the few data available.

fertility. It appeared obvious that cocklebur decayed more rapidly than certain other rotation crops, especially coffeeweed. The amounts of nutrients supplied by the rotation crops and the time of their release can be assumed to affect yield and quality of the tobacco crop.

SUMMARY AND CONCLUSIONS

Six test crops of cigar-wrapper tobacco were grown in 2-year rotations with three summer legume and oat combinations, corn and native vegetation, three native weeds, and three native grasses, with continuous tobacco as the check. The average results showed significant differences in incidence of root-knot and a nematode root rot called coarse root, yield, grade index, crop index, and burn test.

Better tobacco crops were obtained with cocklebur, Texas millet (buffalo grass), and corn-native vegetation rotations than with continuous tobacco. Poor results were obtained with coffeeweed, crotalaria-oats, and goose grass rotations.

No significant correlation was found between root knot index or coarse root index and yield, suggesting the operation of other factors, probably including fertility.

LITERATURE CITED

1. Anderson, P. J. Tobacco culture in Connecticut. Conn. Agr. Exp. Sta. Bul. 364. 1934.
2. Anderson, P. J. Controlling diseases of tobacco. Conn. Agr. Exp. Sta. Bul. 527. 1949.
3. Clayton, E. E., J. G. Gaines, T. E. Smith, K. J. Shaw and T. W. Graham. Control of flue-cured tobacco diseases by crop rotation. U.S.D.A. Farmers' Bul. 1952. 1944.
4. Graham, T. W. Nematode root rot of tobacco and other plants. S. C. Agr. Exp. Sta. Bul. 390. 1951.
5. Kincaid, R. R. Shade tobacco growing in Florida. Fla. Dept. Agr. Bul. 136. 1952.
6. Kincaid, R. R., and G. M. Volk. Effect of soil fumigation of cigar-wrapper tobacco and on soil nitrogen. Fla. Agr. Exp. Sta. Bul. 490. 1952.
7. Kincaid, R. R., and G. M. Volk. Soil fumigation for Florida shade tobacco fields. Fla. Agr. Exp. Sta. Circ. S-45. 1952.
8. Kincaid, R. R., and J. Reeves. Cultural practices for root-knot control between annual crops of cigar-wrapper tobacco. Fla. Agr. Exp. Sta. Bul. 392. 1943.
9. Lunn, W. M., D. E. Brown, J. E. McMurtrey, Jr., and W. W. Garner. Tobacco following bare and natural weed fallow and pure stands of certain weeds. Jour. Agr. Res. **59**: 829-845. 1939.
10. Steiner, G. Letter, Oct. 19, 1944.
11. Steiner, G. Letter, November 4, 1944.
12. Steiner, G. Letter, Sept. 16, 1943.
13. Tarjan, A. C. Letter, May 4, 1951.

13a. Taylor, A. L. Nematode survey in Southeastern states. Pl. Dis. Rep. **28**: 602-604. 1944.

14. Valleau, W. D., and E. M. Johnson. The relations of meadow nematodes to brown root rot of tobacco. Phytopath. **37**: 838-841. 1947.
15. Valleau, W. D., E. M. Johnson and S. Diachun. Tobacco diseases. Ky. Agr. Exp. Sta. Bul. 437. 1942.

SYMPOSIUM: PASTURE SOILS AND PASTURE PRODUCTION IN FLORIDA

PRELIMINARY REPORT OF PASTURE STUDIES IN NORTHWEST FLORIDA

W. R. Langford *

Production of annual row crops including corn, peanuts, and cotton is the primary type of agriculture in extreme Northwest Florida, and until recently there was little demand for information about improved pastures. The first pasture study at the West Florida Station was designed to determine the fertilizer requirements for establishing and maintaining permanent pastures. Results obtained to date from this study, started in 1948, showed establishment of white clover, *Trifolium repens*, and Dallisgrass, *Paspalum dilatatum*, was best where one ton of lime, 180 pounds P_2O_5, and 120 pounds K_2O per acre were applied (1). However, production during the first year was almost as high where 60 pounds of K_2O per acre were applied as where twice that amount was used. Forage yields in subsequent seasons indicate that the annual requirements for maintaining a high level of production may be somewhat less than 180 pounds of P_2O_5 per acre but more than 60 pounds of K_2O per acre. In this experiment superphosphate has been superior to rock phosphate, basic slag, and calcined phosphate.

A large number of grass-legume mixtures were seeded in 1949 as a screening measure to determine which species were adapted to conditions in Northwest Florida. Unpublished data (2) from this study show satisfactory performance of several varieties and species which had not been grown extensively in Northwest Florida and indicated that they should be tested further. These include tall fescue, Pangolagrass, Ladino clover. red clover, Coastal Bermuda-grass and Argentine Bahiagrass.

This is a report of results obtained during the 1952 season from grazing trials and plot studies designed to determine which grass-legume mixtures are best adapted and how they should be grazed to produce maximum returns.

PLOT STUDIES

Five grasses and five legumes were seeded in the twenty-five possible grass-legume combinations on Red Bay soil in November, 1951. The grasses were tall fescue, *Festusa elatior*, var. *arundinacea;* orchardgrass, *Dactylis glomerata;* Pangolagrass, *Digitaria decumbens;* Coastal Bermuda-grass, *Cynodon dactylon;* and Argentine Bahiagrass, *Paspalum notatum.* Legumes seeded in mixtures with these grasses included crimson clover, *Trifolium incarnatum;* red clover, *Trifolium pratense;* Ladino clover, *Trifolium repens;* Kobe lespedeza, *Lespedeza striata;* and birdsfoot trefoil, *Lotus carniculatus.* Each mixture consisted of one grass and one legume. They were seeded in plots six feet wide and seventy-five feet long in randomized blocks. When the mixtures were well estab-

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TABLE 1.—Performance of Grass-Legume Mixtures Under Three Different Mowing Treatments During First Season After Establishment, Jay, Florida—1952

Mixture	March-June				July				August				September				October				Season Total			
	Pounds Oven Dry Matter per Acre																							
	A	B	C	Ave.	A	B	C	Ave.	A	B	C	Ave.	A	B	C	Ave.	A	B	C	Ave.	A	B	C	Ave.
Fescue-Crimson	2504	3476	3731	3237	97			32	450	1176	914	846	441	270	362	357	22	55	44	40	3514	4977	5051	4514
Fescue-Kobe	87	17	123	76	23			8	325	272	624	407	226	152	248	208	43	194	103	113	704	635	1098	812
Fescue-Ladino	860	396	675	644	20			7	601	550	873	675	340	257	388	329	18	212	118	116	1839	1415	2054	1769
Orchard-Crimson	2226	3340	3683	3083	40			13	541	1201	983	908	466	162	393	340	17	30	24	23	3290	4733	5083	4368
Orchard-Kobe	87	50	98	78	28			9	353	545	480	459	222	76	175	158	25	64	35	42	715	735	788	746
Orchard-Ladino	934	388	892	738	15			5	588	616	1111	772	322	118	300	247	18	68	53	46	1877	1190	2356	1808
Pangola-Crimson	2832	3426	4332	3530	669	322	769	587	732	1881	1243	1285	397	189	407	331	25	62	26	38	4655	5880	6777	5770
Pangola-Kobe	37	55	90	91	475	120	362	319	771	1871	1337	1339	355	211	334	300	27	98	53	59	1665	2355	2176	2065
Pangola-Ladino	967	853	663	828	80	13	86	60	964	1631	1884	1493	514	237	255	335	36	87	60	60	2561	2821	2948	2777
Bermuda-Crimson	3162	3551	4795	3806	871	470	889	743	753	2104	1419	1425	483	325	666	491	88	139	94	107	5357	6589	7773	6573
Bermuda-Kobe	100	187	552	280	864	546	802	737	988	2460	1980	1809	628	419	600	559	115	194	126	145	2695	3836	4060	3530
Bermuda-Ladino	1104	514	792	803	418	174	327	306	1429	2566	2066	2020	507	536	808	617	134	235	169	179	3592	4025	4162	3926
Bahia-Crimson	2912	3687	4486	3695	557	296	666	506	678	1715	1617	1337	490	211	371	357	85	71	79	78	4722	5980	7219	5973
Bahia-Kobe	49	45	177	91	239	38	342	205	799	1606	1362	1255	527	228	358	371	114	75	81	90	1728	1992	2320	2013
Bahia-Ladino	1079	752	941	924	72	8	65	48	1122	1446	1520	1363	610	379	516	502	104	99	108	104	2987	2684	3150	2940
L.S.D. 5% level				188				89				241				88				103				

A — Mowed to a height of 1½″ semi-monthly.
B — Mowed to a height of 3″ monthly.
C — Mowed to a height of 1½″ monthly.

lished, each plot was sub-divided into three plots twenty-five feet long, and a different mowing treatment was applied to each subplot. The mowing treatments were designed to simulate insofar as possible a practical method of grazing management. The treatments were: (A), mowed semi-monthly at a one and one-half inch level to simulate close continuous grazing; (B), mowed monthly at a height of three inches to correspond to light rotational grazing; and (C), mowed monthly at a one and one-half inch level to simulate close rotational grazing.

Dolomitic limestone and 4-10-7 fertilizer were applied to the soil at the rates of 2500 pounds and 1000 pounds per acre, respectively, immediately before seeding. A subsequent application of 500 pounds of 0-14-14 was made during June, 1952.

Dense stands of all legumes were obtained, but initial stands of Pangolagrass and Bahiagrass were quite sparse. Clipping treatments were started in March and they have been continued at regularly scheduled intervals. Total oven-dry forage produced the first season by mixtures that contained crimson clover, lespedeza, or Ladino clover are give in Table 1. With one exception, grass contributed very little to the total production of any grass-legume mixture before July. Bermuda-grass that was not suppressed by a cool season legume made considerable growth during June and it accounted for a high percentage of the total forage harvested from Bermuda-grass-lespedeza mixture. Tall fescue and orchardgrass were well established by early March and they restrained the growth of each legume so much that mixtures containing either of these two grasses were less productive than were legumes growing where warm season grasses had not come into production.

The five legumes under study differed widely in their ability to compete with other species. Crimson clover was a strong competitor while birdsfoot trefoil proved quite weak. Trefoil made little growth in association with orchardgrass or tall fescue, but it grew vigorously in plots where warm season grasses remained dormant until late spring. This difference was much less marked with crimson clover. Ladino and red clovers are weaker competitors during the seedling stage than is crimson clover, but they are much stronger than birdsfoot trefoil.

The influence of each legume on forage production of the different grass-legume mixtures is given in Table 2. Mixtures that contained crimson clover produced considerably more total forage during the first season than did mixtures containing any other legume. However, Ladino clover-grass mixtures were somewhat superior to other legume-grass combinations after July. Crimson clover reached a high peak of production during April after which it declined rapidly, but the nitrogen added to the soil by this legume was sufficient to maintain a high level of production by the grass through early July. Droughty conditions during May and July retarded the growth of Ladino and red clovers. This enhanced the superiority of crimson clover over these two species. Birdsfoot trefoil showed considerable drought resistance, but it was attacked severely by Rhizoctonia stem blight. Kobe lespedeza was unable to compete satisfactorily with other species, and it contributed very little to the production of any mixture.

The performance of each of the five grasses is shown in Table 3. Coastal Bermuda-grass-legume mixtures were superior throughout the first season to other grass-legume combinations. Tall fescue and orchard-

TABLE 2.—Performance of Legumes Grown in Mixtures with Five Different Grasses Near Jay, Florida, 1952
Average Production of Oven-Dry Forage by Different Legume Mixtures

Legume	March-June		July		August		September		October		Total
	Lbs./A.	Lbs./A./Day	Lbs./A.	Lbs./A./Day	Lbs./A.	Lbs./A./Day	Lbs./A.	Lbs./A./Day	Lbs./A.	Lbs./A./Day	
Trefoil	286	2.34	126	4.06	926	29.87	333	11.10	87	2.80	1,758
Crimson Clover	3470	28.44	377	12.16	1160	37.41	375	12.50	57	1.83	5,439
Kobe Lespedeza	123	5.05	256	8.26	1054	34.00	319	10.63	90	2.90	1,842
Ladino Clover	787	6.45	85	2.74	1265	40.80	406	13.53	101	3.26	2,644
Red Clover	1172	9.61	96	3.10	1148	37.03	398	13.26	79	2.54	2,893

TABLE 3.—Performance of Grasses Grown in Mixtures with Five Different Legumes Near Jay, Florida, 1952
Average Production of Oven-Dry Forage by Different Grass Mixtures

Grass	March-June		July		August		September		October		Total
	Lbs./A.	Lbs./A./Day	Lbs./A.	Lbs./A./Day	Lbs./A.	Lbs./A./Day	Lbs./A.	Lbs./A./Day	Lbs./A.	Lbs./A./Day	
T. Fescue	1005	8.23	14	.45	618	19.93	291	9.70	98	3.16	2,026
Orchard-grass	979	8.02	10	.32	632	20.38	243	8.10	39	1.25	1.903
Pangola	1234	10.11	244	7.87	1278	41.22	337	11.23	52	1.67	3,145
Bermuda	1360	11.14	474	15.29	1721	55.51	550	18.33	139	4.48	4,244
Bahia	1252	10.26	198	6.38	1284	41.42	410	13.66	86	2.77	3,230

grass failed to grow satisfactorily at any time during this season because soil moisture was inadequate or the temperature was too high after nitrogen became available from the legumes.

Height and frequency of mowing had a marked influence on the yield and stand of some mixtures, but their effect was less pronounced on others. Frequent clipping sharply reduced the yield of crimson clover, but it had little effect on Ladino clover. Ladino clover-grass mixtures produced more under frequent clipping until mid-summer. Furthermore, this treatment favored the establishment of Bermuda-grass and other warm season grasses in association with Ladino clover. After mid-summer all species were favored by infrequent mowing. Stands of orchardgrass and tall fescue were favored by high infrequent clipping while Bermuda-grass and Bahiagrass showed little response to height of clipping.

Significant differences between mixtures also resulted from the influence of one species upon the stand of another. Although crimson clover was superior in yield to other legumes, it retarded the establishment of each grass more than did any other legume. Grass stands are thinner and weeds much more abundant during the summer where crimson clover had grown than in mixtures that contained one of the other legumes. Grass stands are best in mixtures with Ladino clover.

GRAZING TRIALS

Beef-cattle gains obtained during the last half of the 1952 growing season from four grass-legume mixtures are recorded in Table 4. These mixtures consisted of one of four grasses; including Pensacola Bahiagrass, *Paspalum notatum*, Coastal Bermuda, Argentine Bahiagrass, and tall fescue; seeded with a mixture of crimson clover, Ladino clover, and red clover. The pastures are located on Tifton and Carnegie fine sandy loams which are representative of the heavier soils in Northwest Florida. They were fertilized at the time of their establishment during October, 1950, with one ton of dolomitic limestone and the equivalent of 1000 pounds of 0-14-14 per acre. During 1951 they were fertilized with three hundred pounds of 18 per cent superphosphate in March and with 1000 pounds of basic slag and 150 pounds of Muriate of Potash in November. A single application of 500 pounds of 0-14-14 fertilizer per acre was made in September, 1952. In addition to these treatments, the tall fescue-clover pasture received the equivalent of one hundred pounds of Ammonium Nitrate in February and again in September, 1952.

Each pasture was grazed during the late summer and fall of 1951 and, with the exception of tall fescue, throughout the 1952 growing season. However, weighing facilities were not available until July 1952 and gains made prior to that date can only be approximated. It is estimated from the weight of the cattle when purchased and their weight in July that an average yield of 225 pounds of beef gain per acre was made on these pastures from late January through June. Grazing during 1952 was managed so that each pasture was stocked to its capacity. Some were heavily stocked during the spring lush, but the number of animals per acre was reduced during droughty periods when production was low. Tall fescue was grazed lightly during the spring so that the clover could become better established and to allow the fescue to produce seed. Ninety-five pounds of clean seed per acre were harvested from the fescue in

TABLE 4.—BEEF CATTLE GAINS AT THE WEST FLORIDA EXPERIMENT STATION, 1952

Calendar Period of Grazing

Pasture Mixture	July 3-Aug. 4 (32 Days)	Aug. 4-Aug. 20 (16 Days)	Aug. 20-Sept. 10 (21 Days)	Sept. 10-Oct. 4 (24 Days)	Oct. 10-Oct. 30 (20 Days)	Oct. 30-Dec. 8 (39 Days)
Pensacola Bahiagrass-Clover						
Animal per Acre	.94	1.13	1.51	.94	.94	
Pounds Gain/Head/Day	2.44	1.93	2.41	1.58	1.20	
Pounds Gain/Acre	73.6	34.9	76.8	35 8	22.6	
Accumulated Gain/Acre		108.5	185.3	221.1	243.7	
Coastal Bermuda-Clover						
Animals per Acre	.57	1.14	1.70	.94		
Pounds Gain/Head/Day	1.77	2.24	3.02	2.33		
Pounds Gain/Acre	32.0	40.5	107.5	52.8		
Accumulated Gain/Acre		72.5	180.0	232.8	232.8	
Argentine Bahiagrass-Clover						
Animals per Acre*		.94	1.51	.75	.57	
Pounds Gain/Head/Day		2.18	3.10	1 09	1.16	
Pounds Gain/Acre		33.0	98 1	20.0	13.2	
Accumulated Gain/Acre			131.1	151.1	164.3	
Tall Fescue-Clover						
Animals per Acre					1.70	.94
Pounds Gain/Head/Day					1.33	1.36
Pounds Gain/Acre					45.3	50.0
Accumulated Gain/Acre					45.3	95.3

* Cattle used on this pasture were brood cows with calves. One cow and its calf were used as a unit in calculating the animals per acre and the pounds gain per head. Animals on other pastures were steers and heifers that weighed approximately 600 pounds each July 3 and 825 pounds each October 4.

Steer calves averaging 565 pounds were used on each pasture during the period October 10 to December 8.

early June after which this pasture was not used until October. Argentine Bahiagrass was not ready for grazing until August because it was re-seeded in November, 1951. Army worms severely attacked the clover in the Bermuda-grass pasture and the cattle were removed from it October 4 to allow the clover to recover.

Pensacola Bahiagrass in association with clover produced the greatest total beef gain per acre after July 3, but Coastal Bermuda-grass with clover was somewhat superior to other mixtures until it was attacked by army worms in late September. Furthermore, steers on the Bermuda-clover mixture made higher daily gains than did animals on other mixtures. Although the tall fescue-clover mixture was low in total beef production it furnished grazing during the fall when other species were unproductive.

SUMMARY

In a clipping test on Red Bay soil a mixture of Costal Burmuda-grass and crimson clover produced more forage during the first season after establishment than any other mixture studied, but a combination of Ladino clover and Bermuda-grass was superior to other mixtures during late summer. The performance of tall fescue and orchardgrass was unsatisfactory on this droughty soil during 1952. Kobe lespedeza made little growth because it was unable to compete with any of the grasses. Birdsfoot trefoil showed considerable drought resistance, but it was severely damaged by stem blight.

Crimson clover was favored by infrequent mowing while Bermuda-grass-Ladino clover was favored by close, frequent clipping. Crimson clover retarded establishment of grasses which enhanced weed growth after crimson clover matured. Grass stands are best in mixtures with Ladino clover and poorest where crimson clover grew.

Coastal Bermuda-grass was also superior to Bahiagrass in grazing trials until the Bermuda-clover mixture was attacked by army worms. Steers made higher daily gains on Bermuda-grass and its carrying capacity was somewhat higher than Bahiagrass-clover pastures. Although tall fescue was unsatisfactory on Red Bay soil, it furnished abundant grazing during October and November when other species were unproductive.

REFERENCES

1. Gammon, Nathan, Jr., et al. 1950. First Year Yields from Louisiana White Clover-Dallis-grass Pasture Plots on Carnegie and Tifton Fine Sandy Loams, Fla. Agr. Exp. Sta., Circular S-19.

2. Hutton, C. E., Unpublished Report of Progress, West Florida Experiment Station—1950, 1951.

PASTURES IN SOUTH FLORIDA

D. W. Jones and Elver M. Hodges *

There has been a tremendous expansion in the acreage of planted pasture in South Florida in the past seven years. It is estimated that over 75 per cent of the total improved pasture now in use was established in this period. During this same time there was an increase of 380,000 cattle in Florida, according to a report released November 1, 1952, by the Florida State Marketing Bureau. The report further shows that live weight of cattle sold increased by 38,285,000 pounds.

Pasture improvement has progressed from an unknown and questionable innovation to a sound practice giving full value to the livestock industry. Pastures furnish beef cattle with over 90 percent of their total feed. Dairy cattle could use increasing amounts of high quality pasture to decrease cost of production.

Successful pasture plantings have been made on practically all soil types in southern Florida. The largest acreage of pasture has been established on soils belonging to the Ground Water Podzal and the Half-Bog groups. The series making up the highest percentage of these groups are Leon, Immokalee, Pomella, Ona, Rutledge, Scranton, and Plummer sands and fine sands. A relatively small percentage of the total acreage of pasture has been planted on soil belonging to the Red and Yellow Grouping, which includes Norfolk, Lakeland, Eustis, Ft. Meade, and Orlando series. The Bog Soils are being developed for pasture in an increasing amount and this phase of pasture improvement will be discussed in another paper.

It may be said that most of the pastures of South Florida are planted on soils of the Leon, Immokalee and related series primarily because these types predominate in the area. Successful pasture can be produced on all of the soils mentioned if fertilization is adequate.

Herbages grown are divided into two classifications, grasses and legumes. The grasses of this area are for the most part tropical and sub-tropical in nature. Pangola grass is the most popular variety in general use. It establishes quickly, is suited to a wide variety of soil types, survives periodic flooding, and gives excellent growth response to fertilization. A large amount of Pensacola Bahia is being used and the acreage of Coastal Bermuda is increasing rapidly. Para and Carib grass are used extensively in the poorly drained areas. The importance in Southern Florida of Argentine Bahia, Giant Pangola, Buffel and other new grasses has not been fully established.

The value of legumes in a pasture program is recognized by most livestock men in this area. The summer legumes, Alyce clover and Hairy indigo, are being grown, both species being best adapted to well drained soils. For winter legumes, White clover appears to have the most value. It is relatively slow coming into production but has a long season and frequently acts as a perennial. White sweet clover, commonly known as Hubam, is fairly well adapted and is becoming popular as a producer

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Florida Agricultural Experiment Station Journal Series, No. 141.

of winter and spring forage. It is an annual and must be reseeded each year unless sufficient viable seed is produced from the preceding crop. Other winter legumes, grown to a lesser extent, include Alfalfa, Black Medic, Red, Persian, and Sub clovers; some interest is being shown in Big Trefoil. Crimson clovers appear not to have general adaptation to South Florida. Where the fertilization program is adequate, these clovers provide highly nutritious forage during the late winter, spring and early summer months. However, the key to dependable clover production is adequate moisture throughout the clover growing season.

Most sandy soils are low in natural fertility and the lacking elements must be added to produce satisfactory growth. Any attempt to grow good forage without regard to soil fertility requirements is a mistake and can result only in failure. More feed per dollar of cost can be made on pastures well fertilized and managed than from large acreages where plant food needs are neglected.

pH is a valuable measure of soil condition. The majority of virgin sandy soils used for pasture in South Florida have a pH of 4.0 to 5.0. Leaching of plant nutrients is more severe from strongly acid than from slightly acid to neutral soils.

Lime must be added to pasture to adjust the reaction to a desirable range as well as to supply calcium for the plants. A soil pH of 5.5 is satisfactory for grass pastures and on the soils mentioned about one ton of ground limestone per acre is usually required. Two tons per acre of limestone is needed to raise the pH to 6.0 to 6.5, this level being necessary for most legumes.

Grasses in good condition for grazing contain, on a dry-weight basis, about 1.25% nitrogen, 0.25% phosphorus, and 1.0% potassium, as well as varying amounts of other elements. Yields and feeding value of the pasture grasses are lowered if any of these materials are lacking in the soil.

Cattlemen are using the terms *quality* and *protein* synononomously when referring to forage. Protein, or nitrogen, is the feed constituent that is most generally lacking in forages produced on the sandy land of South Florida. Nitrogen is an integral part of the structure of the protein molecule and cannot be omitted from a pasture fertilization program if a large amount of high quality forage is to be produced. In tests on Immokalee fine sand, using Carpet and Common Bahia grasses, the protein content of forage was so low 60 to 90 days following the application of 30 pounds of N that cattle would not utilize it for weight gains. The period of good grazing was slightly longer with Pangola, Pensacola Bahia and Coastal Bermuda with the same fertilizer application.

Phosphorus is low in most soils of South Florida and cannot be omitted from the fertilization program. The addition of 30 pounds of P_2O_5 annually has produced very good pastures. Superphosphate is the most widely used fertilizer phosphate, although some rock, colloidal and triple superphosphate are being used. The value of sulfur carried in phosphatic materials is important and will be discussed in other papers to be given here.

Potassium requirements of pastures on the sandy soils of Florida have not been definitely established. Considering the forage, analyses show that the amount of K required is more than that of phosphorus but less than nitrogen. Gammon in 1951 reported to the Soil Science Society

of Florida that in certain forage plants sodium can substitute for potassium to a relatively large degree.

Minor elements are frequently lacking in soils of South Florida. Copper deficiencies appear to be most common; however, responses to manganese, zinc and borax have been noted also. Geographic boundaries for these deficiency areas have not been determined and, as an insurance against a shortage, these elements are included in the fertilizer program in all areas except where experience has shown that they are not needed.

Current fertilizer recommendations for newly planted pastures on virgin land include 300 pounds per acre of 4-12-6, 5-10-5 or a similar mixture at planting time. This material should contain the necessary minor elements. Heavier rates of fertilization at this time are not necessary, since small plants do not require large amounts of nutrients.

On established sods 400 to 500 pounds per acre of a fertilizer such as 6-6-6 or 8-8-8 will give good results. If the forage can be utilized it is desirable to treat some pastures more than once during the year. Alternate applications of complete fertilizer mixture and of nitrogen make a good combination.

Time of fertilization should be adjusted to provide pasture when needed and certain facts should be kept in mind when working out the fertilization schedule. Some of these are as follows: (1) Best quality of grass is produced during the two months following fertilization; (2) grasses make only limited growth during cool or excessively dry weather; (3) February treatment will stimulate pastures for early spring grazing; (4) August or September applications are needed for fall growth; (5) winter fertilization is not practiced extensively. It is known that quality of forage can be increased by this practice but the quantity produced is not as large as during more favorable growing season.

The final test of a pasture improvement program is its effect on cattle production. The records of three herds of cows kept on different types of pasture at the Range Cattle Station illustrate this point.

Table 1 gives the number in each herd, acres per cow and fertilization plan. The cattle are mostly grade Brahman with some mixture of other breeds. No supplemental feed is given but all groups have access to a complete mineral mixture at all times. Each of these pastures is stocked in accordance with its productive capacity.

TABLE 1.—Number of Cattle in Herds, Acres per Animal and Fertilizer Program

Herd No.	Pasture Type	Cattle in Herd	Acres per Cow	Fertilizer
1	Native	12	13.3	None
2	Combination	70	1.1 Improved 4.5 Native	Spring and Fall None
3	Improved	15	2.0	Spring and Fall

The native range, provided for Herd 1, is about average for flatwoods land. Half of the area is burned annually during the winter.

Herd 2 is kept on a 400-acre area throughout the year. A tract of

eighty acres of this area is improved pasture and another of 320 acres is unimproved. The improved pasture is divided into four 20-acre fields, including one each of Pangola and Coastal Bermuda, one of mixed Bahia-Hairy indigo and one of Pensacola Bahia-Hubam clover. The grass pastures are treated with a complete fertilizer in spring and receive a nitrogen topdressing in the fall. The grass-legume areas receive a phosphate-potash mixture applied in spring for the indigo and in fall for the clover. The cattle are on the native pasture during the entire year and the improved areas one at a time. About one-third of the native range is burned each winter.

The pasture for Herd 3 is entirely Pangola grass fertilized once annually with a complete fertilizer, half of the area in the spring and the other half in fall. This is divided into four equal parts and grazed rotationally in such a manner that a reserve of feed is produced during the late summer and fall months and held for winter grazing.

Table 2 gives the average annual calf, cow and total animal weight gain per acre for each of the three herds. Per-acre calf gains increased in direct proportion to pasture intensification and indicate the value of higher fertility and more productive grass varieties. The yearly increase in weight of cows is not ordinarily a salable return that can be credited to a pasture. It is an indication of pasture conditions that provided enough forage for cattle so that a cow could produce a calf and still maintain herself in better condition. The value of the animal is higher because of this increase.

TABLE 2.—Pasture Conditions as Related to Annual Animal Gains per Acre

Herd No.	Pasture Type	Calf Gain	Cow Gain	Total Animal Gain
		Lbs.	Lbs.	Lbs.
1	Native	19	4.8	23.8
2	Combination	58	8.0	66.0
3	Improved	145	33 0	178.0

Table 3 gives the pounds of calf weight produced per cow and the percentage calf crop. The difference in calf weight produced per cow represent a combination of factors. These are quality and quantity of forage available, grazing and cattle management. Each of these is vital to successful pasture and livestock production. Percent calf crop is an indication of difficulties experienced in both grazing and cattle management. With a breeding herd it is imperative that a high percentage calf crop be produced for largest per acre and per cow return.

The development of the forage improvement program in South Florida has been very extensive. Practically every farm having livestock has some acreage of planted pasture. Fertilization of adapted varieties and strains has progressed from an unknown to a sound practice. The economic production of forage does not insure a profitable livestock

enterprise, since it must be fed to cattle or other animals before a salable product can be attained. The continuing development of a workable system of pasture-cattle management is the greatest need of the livestock production program in South Florida at present.

TABLE 3.—PASTURE CONDITIONS AS RELATED TO PERCENT CALF CROP AND CALF GAIN PER COW

Herd No.	Pasture Type	Calf Crop	Annual Calf Gain per Cow
		%	Lbs.
1	Native	67	261
2	Combination	79	342
3	Improved	71	293

PASTURES IN NORTH FLORIDA

L. G. Thompson, Jr.*

INTRODUCTION

A large acreage of cutover forest land and old cultivated fields, which are too sloping for economical crop production, is being planted in improved pastures in North Florida. High prices of beef and milk have encouraged the establishment of improved pastures and the feeding of beef cattle, especially in Gadsden County. This paper presents a summary of practices used in the establishment and maintenance of permanent pastures, and a brief report of experiments conducted at Quincy, Florida.

PASTURE PRACTICES

Soil Types.—The major well-drained upland soil types used for pasture are Norfolk, Ruston, Red Bay, Orangeburg, Faceville, Magnolia, Marlboro and Plummer fine sandy loams and loamy fine sands. Grady fine sandy loam has been drained and used to some extent for pasture.

Pasture Grasses.—Coastal Bermuda-grass is one of the most important grasses used for permanent pastures. It is usually grown in combination with reseeding crimson clover and is best adapted to well-drained, fertile soils. It is one of the highest yielding grasses on the more fertile soils.

Bahiagrass is an important pasture grass. Two varieties, common and Pensacola, have been used in permanent pastures for many years, and during the last few years, Argentine has been introduced.

Kentucky 31 fescue has been used to a limited extent, but is not recommended because of its high fertility requirement.

Pangolagrass has been tried but at present does not seem to be as well adapted to North Florida conditions as Coastal Bermuda-grass and the Bahiagrasses.

Oats are important for winter grazing, especially during the months of November through February.

Pasture Legumes.—Crimson clover is well adapted and is widely used in the permanent pastures. The reseeding type of Dixie crimson clover is used, because it produces a good volunteer stand. White clover is an important legume, and the Louisiana variety is well adapted.

Hop clovers are well adapted and thrive under lower fertility and soil moisture than white clover. Black medic clover does well on heavy soils, but imported seed is not generally adapted. Annual white sweet-clover (Hubam) may be used as a winter annual; on well limed and fertilized soil it produces a good growth of forage. Common lespedeza is used to some extent in a mixture with grasses for summer grazing.

Cultural and Fertilizer Practices.—The best pasture mixture for fertile soils in North Florida is Coastal Bermuda-grass, crimson and white clover. Coastal Bermuda-grass does not produce seed, so pastures are established by planting stolons. Fifteen to 20 pounds of reseeding crim-

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son clover and 2 pounds of white clover may be planted in the fall, about October, on the Bermuda-grass sod. The seed should be inoculated with at least twice the recommended rate of commercial legume bacteria and planted immediately in moist soil, using a Cyclone seeder or a new type grain drill. Four hundred to 500 pounds per acre of 0-14-10 fertilizer and one ton of calcic or dolomitic lime are applied before planting the clover.

Clover may be ready for grazing by January 1 in favorable seasons, but in most years it cannot be grazed before February 1. When the clover is in full bloom, which is about April 15, the pasture is grazed lightly to allow the clover to produce seed. The residual fertility from the clover produces a good growth of grass.

For maintenance, the pasture should be fertilized in late fall with 400 to 500 pounds per acre of 0-14-10 annually and one ton per acre of calcic or dolomitic lime every five years. Other clovers may be seeded with the crimson and white clover to add variety to the pasture.

Another good pasture mixture for North Florida is Bahiagrass, white and crimson clover. Pensacola Bahiagrass seed is planted ½ to 1 inch deep in the fall on a well prepared, moist soil at the rate of 10 to 15 pounds per acre. Common Bahiagrass should be planted at the rate of about 20 pounds per acre. Oats used as a nurse crop should receive 400 to 500 pounds of a mixed fertilizer such as 5-8-6. The pasture should not be grazed heavily until the grass is well established. As Bahiagrass becomes tough and fibrous when mature, it should be grazed or mowed to reduce seed production.

In the fall when the grass is closely grazed, clover may be introduced and fertilized as previously described.

FIELD TESTS

Field tests with legumes and grasses were initiated on virgin Ruston fine sandy loam in 1946. The fertilizer experiments with clovers and fescue were laid out in randomized blocks with four replications. The sub clover variety test was laid out as single plot treatments on virgin Norfolk loamy fine sand. The crimson clover plots were 16 feet wide and 68 feet long. All other plots were 18 feet wide and 40.3 feet long, except the sub clover variety plots which were 18 feet wide and 80.7 feet long. Fertilizers and lime were applied to the plots by hand and disked into the surface four or five inches of soil. Clover seed was inoculated with twice the recommended rate of commercial legume bacteria and planted immediately in moist soil at the rate of 25 pounds per acre. Fescue was planted at the rate of 15 pounds per acre. The crimson, Hubam and sub clovers volunteered each year for three years. The clover plots were refertilized the second year, but received no additional fertilizer, the third year. Each year the plots were clipped to determine the green weight of forage. The sub clover plots received 500 pounds per acre of a 3-10-6 fertilizer plus 900 pounds of 19 per cent superphosphate and 100 pounds of 50 per cent muriate of potash.

Crimson Clover Fertilizer Test.—On virgin Ruston fine sandy loam, superphosphate gave a large increase in the yield of forage and seed (Table 1). Muriate of potash, dolomitic limestone, borax and nitrate of soda each gave a small increase in yield of forage. Without fertilizer

the yield was almost nothing. Where the plots were refertilized the second year, responses were much smaller. Results show that when the clover was fertilized with 1,000 pounds of 20 per cent superphosphate and 100 pounds of 50 per cent muriate of potash per acre annually for two years, there was sufficient residual fertilizer in the soil the third year to produce luxuriant clover.

TABLE 1.—Crimson Clover Fertilizer Test

Fertilizer — Pounds per Acre					Lbs./A. Ave. of 3 Years	
20% Super-Phosphate	50% Muriate of Potash	Dolomitic Lime	Borax	Nitrate of Soda	Green Weight	Seed in Hull Air Dry Weight
250	100	0	0	0	10,181	728
500	100	0	0	0	15,258	929
1,000	100	0	0	0	17,133	981
500	50	0	0	0	15,085	810
500	100	0	0	0	15,258	929
500	200	0	0	0	16,894	945
500	100	0	0	0	15,258	929
500	100	1,000	0	0	16,260	841
500	100	2,000	0	0	15,621	816
500	100	2,000	0	0	15,621	816
500	100	2,000	15	0	16,373	899
500	100	2,000	30	0	17,223	933
500	100	2,000	0	0	15,621	816
500	100	2,000	0	100	16,282	942

TABLE 2.—Hubam Sweet Clover Fertilizer Test

Fertilizer — Pounds per Acre				Average of 3 Years Pounds per Acre Green Weight
19% Super-phosphate	50% Muriate of Potash	Calcic Lime	Borax	
300	200	6,000	30	11,086
600	200	6,000	30	16,212
900	200	6,000	30	19,369
900	50	6,000	30	14,621
900	125	6,000	30	17,134
900	200	6,000	30	19,369
900	200	2,000	30	14,903
900	200	4,000	30	18,303
900	200	6,000	30	19,369
900	200	6,000	0	15,915
900	200	6,000	15	16,872
900	200	6,000	30	19,369
300	50	2,000	0	7,470
600	125	4,000	15	14,796
900	200	6,000	30	19,369

HUBAM CLOVER FERTILIZER TEST.—On virgin Ruston and Norfolk fine sandy loams, superphosphate, calcic lime, muriate of potash and borax gave large increases in the yield of forage (Table 2). Results indicate that 900 pounds of 19 per cent superphosphate and 125 pounds of 50 per cent muriate of potash annually, plus two tons of lime and 30 pounds of borax per acre every three or four years will produce a luxuriant growth. When the clover was well fertilized for two years, residual plant food was sufficient to produce a good growth the third year.

KENTUCKY 31 FESCUE FERTILIZER TEST.—On virgin Ruston fine sandy loam, nitrogen and phosphate gave large increases in the yield of forage (Table 3). Potash gave a slight response while lime and Es-Min-EL gave no response. The results show that 450 pounds of nitrate of soda and 250 pounds of superphosphate per acre annually were needed to produce a satisfactory growth.

TABLE 3.—KENTUCKY 31 FESCUE FERTILIZER TEST

Fertilizer — Pounds per Acre			Average of 2 Years Pounds per Acre Green Weight
Nitrate of Soda	19% Superphosphate	50% Muriate of Potash	
0	250	100	2,841
800	250	100	8,645
1,600	250	100	12,864
1,600	0	100	5,336
1,600	125	100	9,665
1,600	250	100	12,864
1,600	500	100	14,362
1,600	250	0	10,686
1,600	250	100	12,864
1,600	250	200	11,163

FESCUE AND HUBAM DATE OF PLANTING TEST.—Kentucky 31 fescue planted at about 10-day intervals from November 1 to April 21, produced the most forage from November and December plantings. January plantings made a poor growth, and February, March and April plantings were completely crowded out by weeds during the second year.

Hubam clover planted at weekly intervals during September, October and November, produced the most forage from October plantings.

TABLE 4.— SUB CLOVER VARIETY TEST

Variety of Clover	Average of 3 Years Pounds per Acre Green Weight
Bacchus Marsh subterranean clover	27,830
Dwalganup subterranean clover	8,137
Tallarook subterranean clover	24,079
Mount Barker subterranean clover	27,104

Clover Variety Test.—Talladega and common crimson clovers gave the highest yield, but all seven strains of crimson clover tested made a good growth. Midland and Kenland red, white, Ladino and buttonclovers produced luxuriant growth on well limed and fertilized soil. Bacchus Marsh, Tallarook and Mount Barker subterranean clovers volunteered for three years and made a dense growth of forage, but Bacchus Marsh was heavily infected with mildew (Table 4). Dwalganup sub clover made poor growth and was heavily infected with mildew. Subterranean clovers have been observed to die out under grazing.

SUMMARY

The major well-drained upland soil types used for pasture in North Florida are Norfolk, Ruston, Red Bay, Orangeburg, Faceville, Magnolia, Marlboro and Plummer fine sandy loams and loamy fine sands.

The most important grasses used for permanent pastures are Coastal Bermuda-grass, Common and Pensacola Bahiagrasses.

The important legumes used are crimson and white clovers.

The best pasture mixture for fertile soils in North Florida is Coastal Bermuda-grass, crimson and white clover. Another good pasture mixture is Common or Pensacola Bahiagrass and white and crimson clover.

Permanent pastures should be fertilized with about 400 to 500 pounds of 0-14-10 fertilizer per acre annually and one ton of lime every 5 years.

On virgin Ruston fine sandy loam, phosphate gave the largest increase in yield of crimson clover for forage and seed. Phosphate, potash, and lime gave the largest increase in the yield of Hubam clover for forage. Kentucky 31 fescue responded most to phosphate and nitrogen.

November and December plantings of Kentucky 31 fescue and October plantings of Hubam clover made the highest yield of forage.

All the crimson clover varieties tested made a good growth.

Ladino and white clovers made luxuriant growth on well limed and fertilized soil.

The sub clovers volunteered for three years and made a dense growth, but have been observed to die out under grazing.

PASTURES ON FLORIDA'S PEATS AND MUCKS

R. J. Allen, Jr., and R. W. Kidder*

INTRODUCTION

Areas of peat and muck soils occur to a considerable extent in Central and Southern Florida. By far the most important of these is the Everglades, which is the largest continuous deposit of organic soils in the world, consisting of almost 2,000,000 acres. It lies between the sand ridge on the east coast and the Devil's Garden and Big Cypress Swamp areas on the west, and extends from the south and southeast shores of Lake Okeechobee to the tidal marsh lands at the southern tip of the peninsula.

Other peat deposits are found in the Lake Istokpoga area northwest of Lake Okeechobee, the Lake Apopka or Zellwood area northwest of Orlando, the Weirsdale-Ocklawaha area southeast of Ocala, and along the St. Johns river in the Fellsmere area southeast of Melbourne and the Oviedo area northeast of Orlando.

The first successful commercial herds of cattle on these muck or peat soils were started about 1937 in the Everglades as a result of experiments initiated at the Everglades Experiment Station in 1931. The beef cattle industry in this area has been developed very rapidly during the last ten years and at the present time over 35,000 acres are in improved pasture. Research results on the feeding and breeding of cattle, the introductions of better pasture grasses, and the continuing work on an effective overall flood control and water conservation program have greatly stimulated this development. There has also been considerable pasture development on the other peat areas of the state during the last few years.

NATURE OF MUCK AND PEAT SOILS

The organic soils may be classified as muck, which contains 30 to 65% organic matter, peaty muck, which contains 65 to 85%, and peat, which is 85 to 95% organic.

The inherent or natural fertility of the muck and peat soils varies considerably depending on the element being considered. The nitrogen supply is excellent, the soil nitrogen content being as high as 3 per cent in some cases. This is released slowly but steadily in the decomposition process and, except under conditions of flooding or drought, low soil temperatures, or extreme compaction, when bacterial action is slowed down or stopped, the supply of available nitrogen is ample for good plant growth.

Phosphorus is usually present and available in virgin muck and peat soils in sufficient quantity to promote normal growth. Phosphate fixation, is normally low in virgin peats, but tends to increase slightly as decomposition progresses. Because of this and the normal removal of available phosphate in crops, the requirement for phosphate fertilizer increases as the soil is cultivated and used over a period of time.

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Potassium is very low in muck and peat soils, and large initial applications are necessary. These soils have a high exchange capacity which tends to prevent potash leaching and assures a reasonably efficient use of large annual applications of this element without the use of split applications. Potassium has a tendency to accumulate in these soils with repeated applications and therefore the requirement for potash fertilizer tends to decrease over a period of time.

The supply of calcium and magnesium is very good in all the mucks and peats which are over a limestone base, but it is relatively low in the acid peats. No sulfur deficiencies have been noted.

Copper is the most deficient of any of the trace elements, and symptoms of manganese, zinc, and boron deficiencies have been noted in grasses and other crops in the Everglades. Iron and aluminum are known to be relatively low in most peat areas but no distinct iron deficiency symptoms have been noted on pasture crops. Molybdenum is present in varying amounts in most of the muck and peat soils, and in some cases may be taken up by forage plants in amounts sufficient to be toxic to grazing animals.

PASTURE PRACTICES

Water control is the first requisite in bringing muck and peat soils into actual use for pasture or other crops. A scientifically engineered drainage, flood control, and water conservation program is necessary for the entire area. Also, for each farm or ranch an adequate individual water control system is essential. This system should include a pump installation capable of removing a minimum of one inch of water per day, field ditches adequate to supply the pump by gravity flow, and mole drains through the fields. During the rainy season excess water must be pumped off into the main canals. During the dry winter and early spring months, water must be available in the main canals to be pumped into the field ditches and mole drains in order to maintain proper soil moisture and a constant water table level. Fluctuation between wet and dry conditions will interfere with the nitrification process and will seriously damage the root systems of most pasture grasses.

Virgin peat or muck land is prepared for planting by working with heavy choppers, plows, and harrows until all native vegetation is killed out. An initial application of 500 lbs. per acre of an 0-8-24 fertilizer is generally recommended on virgin peat, followed by annual applications of 300 lbs. of the same analysis. After 4 or 5 years, a change to 0-12-16 at 300 lbs. per acre is recommended. Muck soils may, in general, be treated the same as the older peats.

Initial applications of up to 50 pounds per acre of copper sulfate followed by 12 to 15 pounds annually, or about half of these amounts of copper oxide, are necessary for maximum production of most pasture grasses, and are essential for growth of others such as Pangolagrass, and for the health of grazing animals. MnO at 1.5 per cent, ZnO at 1.0 per cent and B_2O_3 at 0.8 per cent should also be included in the initial fertilizer mixture. Generous applications of lime or dolomite are desirable on the acid peat areas.

The grasses in most general use in the Everglades region are the Roselawn strain of St. Augustine grass, pangolagrass, caribgrass, and paragrass, all of which are planted vegetatively. Bermudagrass is still

being used to some extent and many times will establish itself naturally from seed, especially following vegetable plantings. However, it is not recommended due to lower beef producing ability and to danger of animal photosensitization after light frosts.

Caribgrass and Paragrass are productive and nutritious grasses and will stand considerable flooding, but Paragrass will frequently cause trouble by growing in the water of the drainage ditches, thereby clogging them. Both of these grasses are low in productivity during the winter and are quite sensitive to frost, and they are therefore not suitable in the colder areas north of the Everglades region.

Pangolagrass is a palatable and nutritious grass, somewhat more frost resistant than caribgrass or paragrass but not sufficiently so to be recommended for the very frost susceptible low pockets of the Zellwood or Weirsdale areas.

Roselawn St. Augustine grass is the most vigorous and aggressive strain available and, although not as palatable as some other grasses, it has produced the best beef gains in grazing trials at the Everglades Experiment Station.

The desirability of legumes on muck and peat soils is open to question. Legumes are generally grown for nitrogen fixation and to increase protein content of pasture forage. However, the decomposition and nitrification of muck and peat soils generally furnishes adequate nitrogen to produce a good yield of grass with a relatively high percentage of protein. There is a possibility that fixation of additional nitrogen by legumes may cause nitrate accumulation in the forage with subsequent nitrate poisoning of the grazing animals. It is also known that legumes have in general a greater capacity than grasses for taking up molybdenum, and it is possible that toxic effects may result from this cause. Considerable research work is necessary before legumes can be definitely recommended or condemmed for use on the muck and peat soils.

One of the principal problems peculiar to muck and peat soils is that of subsidence, which is actual loss of soil due to bacterial decomposition or oxidation of the organic matter. Under excessive drainage and constant working for vegetables this loss may amount to one foot in five years, while the loss under pasture use is about ⅓ this amount. It has been shown that a high water table is desirable to slow down the rate of subsidence. This means that less nitrogen will be released, possibly making necessary the application of nitrogen fertilizers or the growing of legumes. Varieties or strains of pasture plants which will give good production under high water table conditions may have to be selected or developed. As the depth of soil decreases the underlying marl rock may influence the pH of the soil possibly to the extent that fixation of trace elements will occur under alkaline conditions. Subsidence also will tend to increase the difficulty and expense of water control.

Another problem is compaction of the soil which occurs after several years in pasture. This reduces the aeration of the soil and slows down the nitrification process, producing symptoms of nitrogen deficiency. Reduced aeration may also decrease the efficiency of the roots to a point where they are unable to take up applications of nitrogen fertilizer.

The copper-molybdenum relationship in regard to plant content and animal nutrition is a factor which is receiving considerable attention as a research problem.

Problems which the organic soil areas have in common with other areas are shortage of winter grazing when the growth of semi-tropical grasses is very slow, seasonal fluctuation in nutritional value of the forage grown, and attacks of insects and diseases.

As in other areas, winter annual forage crops are being grown as supplementary winter pasture and a grass silage study is contemplated. A study involving periodic monthly analysis of forages from pastures under rotational grazing is being initiated and should give a knowledge of seasonal fluctuation in nutritional value, and indicate when the use of high protein supplementary feeds is desirable.

Most pasture crops fortunately are relatively immune or resistant to serious diseases, but aphids, armyworms, and leafhoppers have become more serious as pasture establishment has become more widespread and intensified. A statewide project devoted to pasture insects has been initiated and should contribute towards a solution of this problem.

CONCLUSION

The future outlook for pastures on Florida's organic soils, particularly in the Everglades, points to continued development. These soils subside after drainage whether they are used or not. Therefore, owners who realize this are anxious to put them to use as quickly as possible, and with the possible exception of paddy rice culture, pasturing will cause less subsidence than any other cropping practice.

The productivity or year-round carrying capacity of properly managed Everglades pasture is greater than that reported from any other section of the country, and this fact is drawing considerable investment capital into the area. Research results, and observations and experiences of practical growers, are rapidly solving many of the problems which plagued cattlemen a few years ago.

With its favorable climate, good soil, plentiful water supply, and the know-how to make intelligent use of these resources, the Everglades should become one of the most concentrated and efficient cattle producing areas in the country.

FLORIDA PASTURES FROM THE EXTENSION VIEWPOINT—Abstract

J. R. HENDERSON*

Florida cattlemen have established more than 1,500,000 acres of improved pastures during the last 15 years. In carrying out their pasture programs they have been faced with the necessity of finding solutions to many problems of establishment and maintenance and have sought answers to questions revolving around the following: Soils; varieties; seedbed preparation; liming; fertilization; inoculation of legumes; seeding rates, dates and methods; insect, disease and weed control; and irrigation.

Research workers, at the Main Experiment Station at Gainesville, and at branch stations and laboratories at Jay, Quincy, Live Oak, Ona, Belle Glade, Brooksville, Ft. Pierce and Leesburg, have sought fundamental information, upon which answers to these questions could be based. We, in the Agricultural Extension Service, which serves 64 of the 67 counties in Florida, have been called upon for sound answers based on the available research information.

In attempting to interpret research findings for on-the-farm application, we have recognized and emphasized the fact that many production factors are interrelated. We have felt that the nature of the soil determines, to a large extent, which varieties can be grown and has an important bearing on many management problems. For this reason, we have tried to group soils on the basis of certain characteristics which are known to influence crop adaptation and management practices.

Of the 15 or more soil characteristics that are considered in the detailed classification of soils into types and phases, we feel that the following must be given consideration in carrying out pasture programs: The texture, organic matter content, and reaction of the surface soil; the depth to clay and to water; and the slope of the land.

These major characteristics influence soil moisture and nutrient relationships, and therefore determine which varieties of the climatically adapted pasture plants can be grown, and dictate the liming and fertilization practices which must be used if maximum amounts of high quality forage are to be produced economically from the adapted varieties. Moreover, these characteristics must be considered when determining whether or not irrigation is practical and, if so, what method of irrigation should be used.

The reports from Experiment Station workers which you have heard here this morning have dealt with plant varieties and with some of the management problems in several of the major soil areas of Florida. Others, who will speak this afternoon, will deal generally with specific problems. It is obvious that our research workers are diligently in pursuit of new knowledge. We, in the Extension Service, will continue to look forward eagerly to the release of reports on new findings upon which we can base answers to the many questions that may face Florida cattlemen in the future.

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NUTRITIONAL QUALITY IN PASTURES

GEORGE K. DAVIS and W. G. KIRK*

The final criteria of the nutritional value of pastures are the ways in which livestock grazing those pastures perform. In Florida this is almost synonymous with the performance of cattle on pastures. But by the time cattle give an answer to the question of pasture quality it is usually too late. The cattleman wants to know, before he turns his cattle into a pasture, what he can expect in terms of performance.

Some of the changes that occur during the year in pastures on soils in different areas of the state have a definite bearing on an estimate of pasture quality. In addition the naturally occurring level of plant nutrients in the soil as well as soil amendments influence nutritional quality. Some results of our work may be helpful in assessing the value of a pasture before and during the grazing period.

The total digestible nutrients (TDN) of pasture forage are of primary importance in consideration of pasture quality. Included in TDN are proteins and carbohydrates consisting of starches, sugars and fiber—the tissue building and energy components of the feed. Pasture quality also depends upon the ash, including calcium, phosphorus, magnesium, common salt, potassium, sulfur and the trace elements.

The most critical of these constituents in Florida are protein, fiber, phosphorus and the trace elements with sodium chloride playing an important role along the coast and in some of the peat areas.

We should like to present some data on the protein, fiber, phosphorus and trace element content of pastures during different periods of the year. Since it is obviously impossible to evaluate all the different species, we have limited our discussion to wire grass as an example of native grasses; Pangola as an example of improved pasture; Louisiana White Dutch Clover as an example of a legume; and St. Augustine as an example of grass grown on the peat soil.

Scientists and cattlemen have recognized for a long time that a belly-deep pasture does not in itself guarantee that cattle have an abundance of feed. It is at this point that nutritional quality is a determining factor.

TABLE 1.—PER CENT PROTEIN IN PASTURE FORAGE RELATED TO MATURITY
Dry Matter Basis

Forage	Very Young	Growing	Mature	Old
Wire Grass	10.0	6-7	4	1.5-2.5
Pangola Grass	12-14	9	6-7	2.5-4.0
St. Augustine Grass—Muck	22-28	15-18	10-12	6-9
Clover-Legume	20-22	18-20	10-14	9-12

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Table 1 shows some of the changes which occur in the protein content of grasses during the year. The sharp drop in protein values as the plants age is a good reflection of their nutritional quality, but it doesn't tell the whole story. The dry matter content also reflects the available nutrients. The total fiber gives some indication of digestibility.

Tables 2 and 3 give values for dry matter and fiber for representative samples of the four forages.

Now, for comparison, there are listed in Table 4 some requirements of cattle for dry matter and also for TDN taken from Morrison's *Feeds and Feeding*, 21st Edition.

TABLE 2.—PER CENT MOISTURE IN PASTURE FORAGE RELATED TO MATURITY

Forage	Very Young	Growing	Mature	Old
Wire Grass	85-90	80	70-75	55-65
Pangola Grass	85-90	82	75	65
St. Augustine Grass—Muck	85-90	85	80	70
Clover-Legume	85-90	85	80	75

TABLE 3.—PER CENT CRUDE FIBER IN PASTURE FORAGE RELATED TO MATURITY
Dry Matter Basis

Forage	Very Young	Growing	Mature	Old
Wire Grass	23-24	28-29	30-31	36-40
Pangola Grass	23-24	25-26	27-28	30
St. Augustine Grass—Muck	18-20	24-25	26-28	28-30
Clover-Legume	16-20	20-24	24-25	26-28

TABLE 4.—DAILY REQUIREMENTS FOR CATTLE

	Dry Matter Pounds	TDN Pounds
Growing		
300 lbs.	7.2-9.0	5.1-6.2
600 lbs.	12.4-14.7	8.1-9.3
Maintenance		
Slight Gain		
600 lbs.	11.6-13.3	6.3-7.2
800 lbs.	14.2-16.3	7.7-8.8
Preg. Cows		
900 lbs.	12.1-18.4	6.9-9.7

At this point a little calculation is in order to see what the prospects are for cattle grazing on pastures such as those described in Tables 1, 2 and 3. To meet the needs of a 300-pound beef calf, growing normally, it would take the amount of wire grass forage shown in Table 6. Table 7 shows the relationship for a mature cows. Tables 8 and 9 show a similar setup for Pangola grass.

TABLE 5.—DAILY REQUIREMENTS FOR CATTLE

	Digestible Protein Pounds
Growing	
300 lbs.	.67-.77
600 lbs.	.84-.95
Maintenance	
Slight Gain	
600 lbs.	.67-.75
800 lbs.	.83-.90
Preg. Cows	
900 lbs.	.65-.70

TABLE 6.—POUNDS OF WIRE GRASS TO MEET NEEDS OF 300-POUND CALF

	Digestible Protein	Dry Matter	TDN
Requirement	.67	7.2	5.1
Very Young	64	55	49
Growing	116	36	42
Mature	134	31	38
Old	176	19	34

TABLE 7.—POUNDS OF WIRE GRASS TO MEET NEEDS OF 900-POUND COW

	Digestible Protein	Dry Matter	TDN
Requirement	.65	13.1	6.9
Very Young	63	100	66
Growing	108	65	57
Mature	130	56	51
Old	171	34	45

TABLE 8.—Pounds of Pangola Grass to Meet Needs of 300-Pound Calf

	Digestible Protein	Dry Matter	TDN
Requirement	.67	7.2	5.1
Very Young	54	55	49
Growing	59	40	40
Mature	74	29	34
Old	134	24	34

TABLE 9.—Pounds of Pangola Grass to Meet Needs of 900-Pound Cow

	Digestible Protein	Dry Matter	TDN
Requirement	.65	13.1	6.9
Very Young	52	100	66
Growing	57	73	55
Mature	72	52	46
Old	130	44	46

It should be obvious that, except for the young grasses, protein will be a limiting factor for the young animals. In the case of the younger animals the inability to consume adequate amounts of forage may limit performance too.

Phosphorus also may be a limiting factor as was well demonstrated by Mr. Harold Henderson in his work for the Master's degree. The young grasses exceed the 0.13 per cent of the dry matter as phosphorus that is border line for cattle needs. Young wire grass may have a maximum of 0.2 on good soils but on sandy soils is more likely to have a maximum of 0.16 to 0.18 per cent phosphorus. It responds very poorly to phosphorus applications to the soil.

In old grass, phosphorus values usually are below 0.10 per cent P and often are below 0.05 per cent. Such values are a prelude to phosphorus deficiency in the animals.

In Pangola grass we apparently have a species that responds to the amount of phosphorus in the soil and reflects the soil phosphorus content over a rather wide range. Actually, determinations of phosphorus in Pangola have ranged from 0.04 per cent to 1.01 per cent of the dry matter.

However, a better range is probably from 0.11 to 0.60 per cent. As the grass matures there is a progressive drop in phosphorus content of all grasses. A rule of thumb would be that mature grass will have about

one-half as much phosphorus as young plants and old plants about one-third that of young plants on a dry matter basis.

The trace elements in plants also reflect soil content of these elements. As the plants age, the content drops. Unfortunately, plants are not good indicators of the trace element content in terms of animal requirement. Actually, the cobalt content of any of these plants may range from deficient to surplus at any stage of plant growth. A level of 0.1 ppm in the dry matter is adequate for ruminants. To obtain satisfactory levels, soil amendments amounting to the equivalent of one pound of cobalt sulfate per acre can be made. However, work at the Range Cattle Station has indicated that on Immokalee-type soils renewed applications may be required within three years because of leaching. The economics of cobalt supplementation favor use of mineral supplements in a feeder.

In the case of copper and possibly iron, good-looking plant growth is not a guarantee of nutritional quality. The trace elements must be there either naturally—a fact determined by analysis or by animal performance—or must be supplied as soil amendments or in the mineral box.

The presence of traces of undesirable elements such as molybdenum can also cause a need for copper all out of proportion to that required for plant growth.

Nutritional quality in pasture forage is only partly visible to the eye. The quality that permits top animal performance often lies unseen and unrealized. Protein, digestible nutrients, phosphorus and trace elements must meet animal requirements and it is only good judgment to make sure that the pastures are managed so as to provide for the animals.

COMPARATIVE EFFICIENCY OF VARIOUS NITROGEN CARRIERS

Gaylord M. Volk*

The efficiency of various nitrogen fertilizer materials depends, first, on the nature of the material itself and, second, on a combination of factors involving the crop, the soil, cultural practices and climatic factors. Two factors which characterize the materials are the ease with which their nitrogen is leached from the soil and the relative rate of availability of their nitrogen to the plant.

A simple grouping of materials places all nitrate nitrogen, regardless of source, in the easily leached but highly available class. All ammoniates, regardless of source, also are classed together. They are held to a considerable extent by the soil against leaching, have fair acceptability to most plants, but convert quite rapidly to the nitrate form and then assume its characteristics.

Urea and Cyanamid belong to the soluble organics group. Their nitrogen converts rapidly to ammonia in the soil and then follows the usual pattern. The only exception is the non-calcium cyanamid fraction in Cyanamid. Evidently this fraction, which amounts to about 4 per cent of the approximately 20 per cent total guaranteed by the manufacturer, converts more slowly in the soil and does give some of the characteristics of the more slowly available natural organics.

Duramene is a representative of the newer synthetic forms of more slowly available nitrogen made by polymerizing urea and formaldehyde together. In this case it is in combination with wood waste, and the nitrogen supplied by the urea is definitely retarded in rate of availability and in potential movement and loss through leaching.

The last group of interest includes the natural organics. They are the seed meals, tankages and sludges used in the raw state, or after treatment with heat or chemicals or both. Their primary difference from the preceding materials is their slow or controlled rate of availability with subsequent lessened hazard of loss by leaching. They are materials which have an initial high cost per unit of nitrogen, and the organic materials generally used today in mixed fertilizers have a relative low total effective availability of the nitrogen they contain.

Ammoniated superphosphate, which has come into widespread use because it utilizes the relatively cheap ammoniating liquors, usually contains both ammonia nitrogen and nitrate nitrogen. Anhydrous ammonia, another cheap form of nitrogen, has real promise for pastures under some conditions. For practical purposes, it may be considered as identical with other sources of ammonia nitrogen once it has been injected properly into the soil.

Of the numerous forms of nitrogen in fertilizer materials, it is sufficient that a comparison of ammonia nitrogen to nitrate nitrogen be used to determine their relative efficiency for pasture grasses. The rate of conversion of other materials to ammonia, as in the case of urea, or the

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Florida Agricultural Experiment Station Journal Series, No. 93.

initial high cost, as in the case of natural organics, is either well known or eliminates the material from practical usage. However, in order that some understanding of how certain of these materials convert in the soil, Tables 1, 2 and 3 have been included.

TABLE 1.—COMPARATIVE AVAILABILITY AND RETENTION OF DURAMENE 20, COTTONSEED MEAL AND URAMON, USING OATS AS THE TEST CROP

Arredondo Loamy Fine Sand in Three-Gallon Coffee Urn Type Pots

Treatment	Yield in Grams D.W.				Nitrogen Recovery by Plants		Percent Nitrogen Leached
	3/1	3/15	4/17	Total	Grams	Percent	
0.5 g. N from Duramene 20	3.51	2.68	7.29	13.5	.362	72%	
0.5 g. N from Duramene 20 (Leached)	2.89	2.16	7.03	12.1	.281	56%	16%
0.5 g. N from Cottonseed Meal	3.77	2.92	6.52	13.2	.351	70%	
0.5 g. N from Cottonseed Meal (Leached)	3.34	2.34	6.47	12.2	.299	60%	15%
0.5 g. N from Urea	5.29	4.17	6.74	16.2	.492	98%	
0.5 g. N from Urea (Leached)	5.13	3.09	5.83	14.0	.384	77%	25%
0.64 g. N from Calcium Nitrate (1)	4.13	4.18	8.19	16.5	.586	92%	
0.64 g. N from Calcium Nitrate (1) (Leached)	3.48	2.13	4.81	10.4	.270	43%	70%

(1) Used as check to show that maximum nitrogen response had not been exceeded in other treatments and that leaching was effective.

Fertilized and planted February 5. Leached with one inch of water on 2/14, 2/22, 3/6 where indicated.

L.S.D. total yield 5% point is 1.0 grams.

L.S.D. nitrogen recovery 5% point is .022 grams.

Table 1 shows a comparison of Duramene 20 (20% N), cottonseed meal, urea and calcium nitrate with respect to their availability to oats and the ease of leaching loss from three-gallon greenhouse pots. Nitrogen recovery by oats from Duramene and cottonseed meal was similar at about 70 per cent for the period, but recovery from the urea and the calcium nitrate exceeded 90 per cent in the same period. Urea converts to ammonia in a matter of only three to four days, so it functions essentially as an ammoniate. Where leaching was practiced it was found that only 15 to 16 per cent of the nitrogen of the first two materials was re-

moved, while 25 per cent of the nitrogen from urea and 70 per cent of the nitrogen from the calcium nitrate was lost. Table 2 shows that this loss took place during the first two leachings.

TABLE 2.—TIME OF LEACHING OF SOLUBLE NITROGEN FROM DURAMENE 20, COTTONSEED MEAL AND URAMON, IN THREE-GALLON POTS

Leached with One Inch of Water on Each of Four Dates Shown

Treatment	2/14	2/22	3/6	3/15	Total	Percent Nitrogen Leached
0.5 g. Nitrogen from Duramene 20	.063	.017	T	T	.080	16%
0.5 g. Nitrogen from Cottonseed Meal	.047	.029	T	T	.076	15%
0.5 g. Nitrogen from Uramon	.069	.058	O	O	.127	25%
0.64 g. Nitrogen from Calcium Nitrate	.154	.296	O	T	.450	70%

Fertilized and planted to oats February 5.

Equivalent potash as sulfate was returned to pot as soon as leachate was analyzed. This amounted to 12 to 13% of the original on 2/14 and dropped to half this by 3/15.

No NH_3 nitrogen or phosphorus leached.

L.S.D. 5% point — .007.

TABLE 3.—COMPARATIVE RATES OF NITRIFICATION OF DURAMENE 20, COTTONSEED MEAL AND URAMON

Incubated at 28°C. in Arredondo Loamy Fine Sand at Optimum Moisture

Treatment: 100 ppm Nitrogen Added to Soil from the Following:		PPM Nitrogen Found as NH_3 and NO_3 at: 9 Days	14 Days	18 Days	24 Days	31 Days	38 Days	52 Days
Duramene 20	NH_3	10	3	2	2	----	----	----
	NO_3	28	42	82	57	70	82	83
Cottonseed Meal	NH_3	13	----	----	2	----	----	----
	NO_3	30	50	61	72	82	90	86
Uramon	NH_3	53	13	3	2	----	----	----
	NO_3	49	81	101	114	114	125	127
None (Check)	NH_3	2	----	----	3	----	----	----
	NO_3	9	13	31	19	32	26	33
Calcium Nitrate	NH_3	----	----	----	3	----	----	----
	NO_3	86	101	117	109	118	115	130

Table 3 shows the rate of conversion of the various forms of nitrogen to the ammonia and nitrate forms under controlled conditions, and explains why the losses from the urea and calcium nitrate were high as compared to the slowly nitrifying Duramene and cottonseed meal. Obviously, the relative power of a soil to convert ammonia nitrogen to nitrate nitrogen will have much to do with the loss resulting from a leaching rain at any given time and will determine what type of nitrogen the plant will have to use at various stages in its growth. That this type of conversion takes place rapidly in fertile soils is well known to the majority of agriculturists, but the fact that certain Florida soils, especially those in virgin condition, do not nitrify ammonia rapidly is a little-appreciated problem in the pasture development program of the state.

TABLE 4.—EFFECT OF LIME AND INOCULATION ON NITRIFICATION OF VIRGIN IMMOKALEE FINE SAND, FORT PIERCE AREA

No.	Treatment (1)	PPM Nitrogen in Soil					
		Ammonia		Nitrate			
	Weeks	1	2	1	2	4	8
1	Check			.3	.3	.7	.6
2	Lime		22	.2	.3	21.9	46.7
3	Lime, $CaNO_3$			95.0	97.0	106.1	152.4
4	Urea	101	108	.3	.3	.8	.4
5	Urea (2)		107	.2	.2	.8	.7
6	Lime, Urea (2)	94	35	1.9	12.9	20.1	62.2
7	Lime, Urea	108	112	.2	.2	11.8	25.1
8	Lime, Urea (1)		114	.2	.3	18.3	51.4

(1) All except No. 8 received 100 ppm. gypsum, 100 ppm. Es-Min-El (a commercial mixture of secondary elements), 56 ppm. P_2O_5 from $Ca(H_2PO_4)_2$, 54 ppm. K_2O from K_2SO_4. 100 ppm. N added where indicated. 1500 ppm. lime as precipitated chalk.

(2) 400 gm. inoculated with 10 ml. of 1-2 settled suspension of Arredondo loamy fine sand of high nitrifying capacity. All incubated at 12% moisture approximately 28°C.

There is indication that added salts and urea may have had some depressing effect on nitrifiers, secondary to the effect of lime and inoculation.

Table 4 shows what happens when urea is added to virgin Immokalee fine sand and incubated under standard conditions. Lime obviously helped the nitrification, as shown by treatments 2 and 7, but the addition of a good inoculating suspension was necessary to produce the most rapid conversion of urea to nitrate. Under field conditions this characteristic of certain virgin Florida soils undoubtedly will be a factor in comparing responses to ammoniates and nitrates and must receive attention in research work. The application of lime only to the surface, or its poor incorporation in the plow depth, probably will result in retarded nitri-

TABLE 5.—LEACHING LOSS OF NITROGEN AND YIELDS OF THREE GRASSES UNDER VARIOUS NITROGEN SOURCES
1951 Data from 1/2000 A. Lysimeters of Lakeland Fine Sand, Four Feet Deep

Nitrogen Source	Inches Water Leached				Pounds NO_3-N Leached				First Cutting Grass Yield—5/19			Total Grass Yield		
	3-7 to 6-19	6-20 to 8-9	8-10 to 9-7	Total	3-7 to 6-19	6-20 to 8-9	8-10 to 9-7	Total	D.W. #/A.	% N	Total #N	D.W. #/A.	% N	Total #N
Carpet Grass														
NH_4NO_3	3.30	5.41	3.88	12.6	.76	.16	.06	.99	158	1.43	2.2	2922	1.13	33.0
Urea	3.86	5.48	3.97	13.3	.40	.10	.04	.54	559	1.09	6.1	3216	1.08	34.8
$NaNO_3$	3.28	5.49	4.02	12.8	.26	.08	.05	.39	352	1.15	4.1	3274	1.05	34.4
$NaNO_3$*	3.88	5.45	3.94	13.3	.80	.13	.10	1.03	260	1.26	3.3	3687	1.10	40.5
Pensacola Bahia														
NH_4NO_3	2.27	5.45	3.94	11.7	.04	.11	.07	.21	884	1.27	11.2	4356	1.11	48.5
Urea	2.29	4.84	3.74	10.9	.02	.15	.06	.23	999	1.29	12.9	4105	1.08	44.4
$NaNO_3$	2.24	4.25	3.79	10.3	.04	.20	.07	.31	1008	1.26	12.7	4352	1.07	46.8
$NaNO_3$*	2.44	4.87	3.83	11.1	.07	.11	.10	.29	1219	1.25	15.2	5034	1.05	52.9
Pangola														
NH_4NO_3	3.37	5.16	4.18	12.7	.23	.10	.04	.38	906	1.04	9.4	4189	0.82	34.5
Urea	4.04	4.87	4.23	13.1	.10	.07	.04	.22	761	1.14	8.7	4510	0.81	36.5
$NaNO_3$	3.72	5.13	4.31	13.2	.15	.12	.05	.32	1162	0.91	10.8	5016	0.79	39.6
$NaNO_3$*	2.99	4.95	3.93	11.9	.05	.07	.05	.17	1245	1.12	14.0	4690	0.87	40.7

All received 20 lbs. N on 3-7, 5-11. 7-10 as indicated, except $Ca(NO_3)_2$ substituted for $NaNO_3$ on 5-11, 7-10.
Na equalized with $NaHCO_3$.
200 lbs. $MgSO_4.7H_2O$, 222 lbs. K_2SO_4, 212 lbs. $Ca(H_2PO_4)_2.H_2O$, 360 lbs. $CaSO_4.2H_2O$ added 3-7.
All determinations in this and following tables are on forage of 10% moisture content.
* Above sulfates substituted with chlorides of equal base equivalent.
Rainfall was 5.0, 2.2, 2.3, 4.0, 9.7, 11.0, 7.5 inches, March to September, respectively.
0.25 inch tapwater added after each fertilizer application. It contained 3 lbs. Na per acre inch.

fication as compared to soils initially at a favorable pH or in which the lime is thoroughly incorporated.

To get a better understanding of the efficiency of nitrogen for various grasses, twelve 1/2000-acre lysimeters of four-foot depth were filled with Lakeland fine sand by profile and planted to different grasses. They were fertilized with various sources and amounts of nitrogen in conjunction with other elements. Data appear in Tables 5, 6, 7 and 8.

TABLE 6.—LEACHING OF NON NITROGEN CONSTITUENTS FROM $NaNO_3$ TREATMENTS, POUNDS PER ACRE

(See Table 5 for Treatment Detail)

Grass	Sulfate Form				Chloride Form			
	3-7 to 6-19	6-20 to 8-9	8-10 to 9-7	Total Loss	3-7 to 6-19	6-20 to 8-9	8-10 to 9-7	Total Loss
Potassium								
Carpet	0.7	2.3	1.4	4.4	1.1	1.5	0.5	3.2
Bahia	0.3	2.7	0.9	3.9	0.4	2.8	0.5	3.7
Pangola	0.3	0.4	0.2	1.0	0.3	0.4	0.1	0.8
Sodium								
Carpet	4	29	9	42	7	20	8	34
Bahia	3	27	11	41	4	29	9	42
Pangola	4	25	8	38	3	18	5	26
Calcium								
Carpet	10	69	26	104	46	77	11	135
Bahia	9	57	31	97	16	109	11	136
Pangola	19	68	32	119	25	88	8	122
Magnesium								
Carpet	1.8	11.1	4.4	17.3	3.2	10.7	1.4	15.3
Bahia	1.4	6.8	3.8	11.9	1.8	15.0	1.6	18.4
Pangola	2.4	9.7	5.0	17.1	3.5	12.2	1.1	16.9
Sulfate (SO_4)								
Carpet	40	260	90	390	22	33	24	79
Bahia	16	212	107	335	15	31	25	71
Pangola	54	265	106	425	19	32	30	81
Chloride (Cl)								
Carpet	3	6	2	11	97	176	13	286
Bahia	0	7	1	8	22	239	12	272
Pangola	1	2	1	4	48	199	1	247

TABLE 7.—EFFECT OF NITROGEN SOURCE AND QUANTITY ON YIELD OF FOUR GRASSES IN 1/2000 ACRE LYSIMETERS, 1952

Treatment Lbs. N and Source (1)	D.W. Yield Tons/Acre	N in Harvest Lbs./Acre	Per Cent of N Application in Harvest	Percent of N Residual in Form of Nitrate (2)
		Pangola Grass		
480 Urea	7.6	261	54%	1.5%
480 NH_4NO_3	7.7	269	56%	1.6%
240 NH_4NO_3	5.9	139	58%	1.1%
		Carpet Grass		
480 Urea	3.6	137	28%	16.9%
480 NH_4NO_3	3.6	129	27%	16.9%
240 NH_4NO_3	2.5	71	30%	5.1%
		Pensacola Bahia Grass		
480 Urea	6 3	223	47%	0 1%
480 NH_4NO_3	6.6	230	48%	0.4%
240 NH_4NO_3	4.6	120	50%	0.1%
		Coastal Bermuda Grass		
480 Urea	6.6	280	58%	1.2%
480 NH_4NO_3	7.6	272	57%	2.9%
240 NH_4NO_3	4.2	104	43%	1.0%

(1) Nitrogen was applied the first of each month at 30 or 60 pounds for 8 months beginning in March. Thirty pounds each of P_2O_5 and K_2O were applied each month. One hundred pounds of Es-Min-El was applied in March only.

(2) Rainfall was unusually uniform for the growing period as seen from Table 8. Lysimeters were leached with tap water at the end of the above period to obtain residual nitrate nitrogen. Natural leaching was negligible except for carpet grass. Nitrogen so removed was added to the residual.

A total of only 60 pounds of nitrogen was used for the 1951 tests reported in Tables 5 and 6. That this was insufficient to produce yield differences between potentially high producing grasses is obvious. There were no marked differences from the different sources of nitrogen used. The percentage of nitrogen was low in grasses in all instances. It was about 1 per cent for carpet and Pensacola Bahia, and only about 0.8 per cent for Pangola. The Bahia was the most efficient user of the nitrogen, in that its harvest accounted for 77 per cent of the application, while carpet was poorest. These data indicate a characteristic difference between Pangola and Pensacola Bahia grasses, in that the former will produce lower nitrogen content forage under limited nitrogen supply than will Bahia.

Out of a total of 42 inches of rainfall during the period, approximately 12 inches leached through the lysimeters, but this removed less than one pound of nitrogen in almost all instances.

TABLE 8.—MONTHLY VARIATION IN YIELD AND NITROGEN CONTENT OF TWO GRASSES IN 1/2000 ACRE LYSIMETERS

Rainfall (1)		Pangola (2)			Pensacola Bahia (2)		
	Inches	Harvest Lb. D.W.	% N in Harvest	% N (3) Application in Harvest	Harvest Lb. D.W.	% N in Harvest	% N (3) Application in Harvest
Mar.	2.5	995	2.2	37	1001	2.4	40
Apr.	3.4	1571	1.4	37	1224	1.9	38
May	4.6	2491	2.0	83	2029	1.8	61
June	3.5	1379	1.9	44	2084	1.5	58
July	4.1	3574	1.2	74	3135	1.2	64
Aug.	4.2	1415	2.5	58	1331	2.0	45
Sept.	4.9	1467	2.0	48	1534	2.0	54
Oct.	4.9	2308	1.6	62	574	2.4	24

(1) Includes ¼ inch of tap water used each month to wash in fertilizer.

(2) Data are the average of 60 pounds N per month Urea and NH_4NO_3 treatments, Table 7.

(3) This shows the percentage of the 60 pound nitrogen application appearing each month. Fertilizer was applied just after harvest at the end of each month.

Table 6 records the leaching losses of non-nitrogen constituents. The loss of potassium was less than five pounds in any instance, but losses of sodium, calcium, sulfur and chlorine were high, as would be expected.

Tables 7 and 8 present the data from the 1952 tests in which up to 60 pounds of nitrogen per month for eight months was applied. Here the real abilities of the various grasses to use nitrogen are apparent. There was a marked difference between carpet grass and the other three grasses —Pangola, Bahia and Coastal Bermuda—to utilize high rates of nitrogen. The carpet produced only about one-half the yield and showed an efficiency of only about 28 per cent as compared to from 47 to 58 per cent for the others. Thirty pounds of nitrogen produced from 55 to 76 per cent as much yield as did the 60 pounds, but the actual nitrogen uptake was about one-half in all instances.

After deduction of the residual nitrate nitrogen at the end of the period, it is apparent that up to 50 per cent of the nitrogen is still unaccounted for. Possibly the majority of this was used for root growth in that these sods were still only three years old for all except the Bermuda, which was in only its first year. Higher efficiency might be expected when the sods reach an age such that decomposition of old roots equal the production of new, and thus reach a closer balance of nitrogen for root production. How much of this would be lost during winter leaching is not known but continuation of the lysimeter tests may answer this question. It also is intended to sample these soils by profile in an attempt to account for some of the lost nitrogen.

There was no consistent difference between urea and ammonium nitrate as sources of nitrogen in this test. Both appear to be good sources of nitrogen if leaching is not a factor. The year 1952 was an exceptional one in that little significant leaching took place. It made an excellent test of the ability of the grasses to use the different forms of nitrogen but did not evaluate the differential leaching losses that could be expected if heavy rains followed immediately after fertilization while the ammonia

still existed as such and could be held by the soil, as compared to the high mobility of nitrates. The soil used in these lysimeters was not in virgin condition but had ample rate of nitrification to supply nitrate from applied urea if the grass preferred the nitrate form.

Table 8 is included to show the effect of time of season on growth and nitrogen content of Pangola and Pensacola Bahia grasses. Yield, percentage of nitrogen, and efficiency of the grasses varies widely. It is quite inconsistent in the case of the Pangola but quite orderly in case of the Bahia. The answer may lie in the type of root system of the grasses. Lysimeters of this type have a major fault in that they store a certain amount of water in the lower depths. The uniformity of the Bahia data suggests that this grass might be deeper rooted and taking advantage of this subsoil moisture so that fluctuations in actual rainfall were less disastrous to growth. On the other hand, Pangola appeared to reflect the variations in rainfall, which actually were much wider than the simple monthly totals indicate.

In conclusion, it appears that the yield possibilities of our better grasses are limited only by rainfall. Even 480 pounds of nitrogen for the season did not reach the maximum in yield and nitrogen content of the grass. Where the economical efficiency of nitrogen utilization, in keeping with acceptable quality, lies is still unknown and will be determined largely by the pasture program for any given production unit. The questions to be answered will be how much should a given amount of nitrogen be limited to a small area for maximum per acre yield, or spread over a large area for maximum gross yield of lower quality forage; and how closely should effective rainfall control the fertilizer program. It appears that there may be considerable leeway in selecting nitrogen sources, unless poor nitrification in virgin flatwoods soils or leaching losses of nitrate become significant factors. The possibility of developing toxic amounts of nitrate nitrogen in the forage always exists, but in these tests 0.04 per cent nitrate nitrogen was the maximum abserved.

BURNING TO ESTABLISH AND MAINTAIN CLOVER PASTURES

G. B. Killinger*

Burning of native pasture vegetation such as wiregrass, palmetto, gallberry and other woody pasture plants has been a common practice in Florida and other Southern states. An experiment which consisted of burning several areas each year over a ten-year period was compared with several not-burned areas adjacent to the burned areas, both with year-round grazing. The annual burned areas yielded 10 pounds of beef per acre per year while the unburned areas produced 5 pounds of beef per acre per year.[1]

This experiment was conducted at one location in the state on Leon fine sand. This pasture burning experiment was rather conclusive proof, at least for the one location, that the burning of native pastures would increase beef gains; at the same time beef yields were increased further by burning and top-seeding carpet grass on the ash seedbed. By 1941 it had been well established at several locations by the Florida Agricultural Experiment Station that carpet grass could be seeded on burned-over wiregrass pastures with a resulting satisfactory stand and growth of carpet grass.

It was found that June, July and August burns of native pasture, with immediate seeding of carpet grass, was better than burning at other seasons of the year. June, July and August are off-season burning months. Grass burned at this time was noticeably retarded for several years, as compared to wiregrass burned during the December to March period, which is the time most cattlemen burn their pastureland.

From 1942 to 1952 numerous experiments were conducted on native and improved grasses involving the use of fire as a means of establishing and maintaining stands of winter and summer legumes.

In establishing winter legumes the soil acidity was first determined. The limestone necessary to raise the pH to 5.8 to 6.5 was applied several months in advance of burning whenever possible. Burning was done on a quiet (windless) day between October 20 and November 5 when the soil was damp to wet. The best time to burn wiregrass was found to be between 1 p.m. and 3 p.m., with the fire started on the side away from the wind and allowed to burn slowly, eating its way into the wind. This technique in burning accomplished a clean and thorough burn.

Thermometers placed horizontally at the soil level and slightly creased into the soil—however with the face exposed—showed an increase in temperature during the fire of from 3 to 8 degrees C. while the temperature 8 - 10 inches above the soil surface ranged from 200 to 500 degrees C. Burning vegetation growing on a moist soil, with little wind movement, allows for a blanket of moisture to form at the soil surface which protects the soil itself from the effects of a hot fire. The same effect is

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[1] W. E. Stokes, et al.: Annual Report, Florida Agricultural Experiment Station. 1938. Page 41 and unpublished data.

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achieved when the wind is blowing by burning into the prevailing wind. Thus, with proper burning, probably very little soil organic matter will be lost other than the accumulated matter on the surface not already incorporated or decayed to the point of being a part of the soil.[2]

As soon as the fire died down on the burned-over plots or pasture area, inoculated clover seed were broadcast at the recommended rate and 500 to 600 pounds per acre of an 0-12-12 or similar fertilizer was surface applied. No seedbed preparation was required, as the ash from a good burn makes an excellent medium in which to germinate small-seeded legumes. The same procedure worked well in the spring for starting lespedeza or Hairy indigo, as well as being satisfactory for most of the seeded pasture grasses. To date, there has never been a failure on these experiments in nodulation; this includes inoculation of Big Trefoil on which it is known that adequate nodulation is difficult to obtain.

Burning of improved pastures for establishing and maintaining clover stands has proven satisfactory also. Plot experiments with permanent sods of Carpet, Coastal Bermuda, Pangola and Common Bahia grasses were seeded to White clover on Leon fine sand near Gainesville, Florida, in the fall of 1946. Starting in the fall of 1947, eight replicates of each grass were burned, with an equal number left in a rather tall sod condition. All plots received the same fertilization throughout the experiment.

TABLE 1.—Per Cent Increase of Volunteer Clover Plants

Over Tall Sod			Over Mowed
Grass Sod	Mowed	Burned	Burned
Carpet	2441	5500	120
Coastal Bermuda	1625	3362	95
Pangola	611	1817	170
Common Bahia	1170	3074	150

1947 and 1948.

Results of these experiments are given in Tables 1 and 2, and are self explanatory. These show the percentages of volunteer clover from mowing and burning over the clover found growing under tall sod conditions. Table 2 also shows a sizeable increase in total clover and grass herbage for the season from the burned plots as compared to the mowed plots.

To insure a good volunteer stand of winter clovers, it is first necessary to know there is sufficient clover seed in the sod and it is also necessary to remove as much grass as possible by grazing, mowing or burning to allow sunlight to reach the very tiny seedlings trying to make a start.

The burning data presented in the two tables also indicate a possible seed scarification effect from either the fire or the ash.

[2] Frank Heyward and R. M. Barnette. Effect of Frequent Fires on Chemical Composition of Forest Soils in the Longleaf Pine Region. Florida Agricultural Experiment Station Bulletin 265. 1934.

The author wishes to acknowledge the early work of W. E. Stokes and W. A. Leukel on pasture burning techniques and the work of R. E. Blaser on clover establishment in Florida.

TABLE 2.— Per Cent Increase of Clover and Herbage from Burning Over Mowing

Grass Sod	Clover Plants	Herbage (Clover and Grass)
Carpet	421	65.3
Coastal Bermuda	243	46.7
Pangola	82	41.3
Common Bahia	776	84.7

1949 and 1950.

SULFUR VERSUS PHOSPHORUS FOR SOILS IN PASTURES OF FLORIDA

J. R. NELLER*

The acreage of planted pasture continues to increase throughout the state. These new areas, together with those already in improved pasture, must be fertilized regularly and properly to insure a profitable return on the investment.

In their virgin state most of the soils of the pastures of Florida are deficient in phosphorus as well as in nitrogen and potassium. For some time it had been known that some areas were deficient in sulfur also, particularly for legumes. More recently a deficiency in sulfur has been found to be extensive throughout most of peninsular Florida. This was determined by field plot experiments established and maintained for several years in areas representative of the extensive sandy flatwoods of the peninsula.

EXPERIMENTAL

The experimental areas were prepared by killing off the native cover of wiregrass and palmetto with heavy disks designed for the purpose. Ground dolomitic limestone at two tons per acre was disked into the surface three to four inches, bringing the pH to about 5.5. The soil was disked lightly and occasionally thereafter for about a year. Plots arranged in a randomized block design were then fertilized with the phosphate and sulfate carriers recorded in Table 1. Potash and phosphate were applied annually in amounts equivalent to those in an 0-14-20 fertilizer at 500 pounds per acre. Rock phosphate was used at one ton per acre once only, but potash was applied annually in the fall. Minor elements were applied initially to insure that the only variable should be that of gypsum as a source of sulfur. Previous experiments had shown that the phosphates as used were an adequate source of phosphorus. Experimental plots of the pasture areas of sandy loams in West Florida were prepared in a similar manner.

Table 1 summarizes the type of growth response that was obtained in these experiments. For the sandy flatwood soils of peninsular Florida it may be seen that omission of gypsum to furnish sulfur in the fertilizer program resulted in an almost complete failure of White Dutch clover. These results are illustrated in Figures 1 and 2. Growth of the associated grass during the summer months was in most cases of higher tonnage and in all cases of higher protein content where clover grew during the winter because of addition of a source of sulfur to the fertilizer. On the average, there was about five times as much protein produced by the forage annually where a sulfur fertilizer had been added.

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Sincere appreciation is expressed to H. W. Lundy, D. W. Jones and G. B. Killinger for their kind cooperation in obtaining growth data; and to R. W. Bledsoe for plant analysis.

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TABLE 1.—EFFECT OF ADDITION OF GYPSUM AND PHOSPHATES UPON GROWTH OF CLOVER AND ASSOCIATED GRASSES IN PASTURE AREAS OF PENINSULAR FLORIDA AND OF WEST FLORIDA *

Gypsum and Phosphate Treatments	Flatwood Sands of Peninsular Florida		Sandy Loams of West Florida	
	Clover in Winter	Grass in Summer	Clover in Winter	Grass in Summer
Superphosphate	100	100	100	100
Rock phosphate	7	106	76	96
Rock phosphate + gypsum	111	97	68	104
Calcined phosphate	8	114	82	87
Calcined phosphate + gypsum	98	137	132	108

* Amounts given are relative to those for superphosphate.

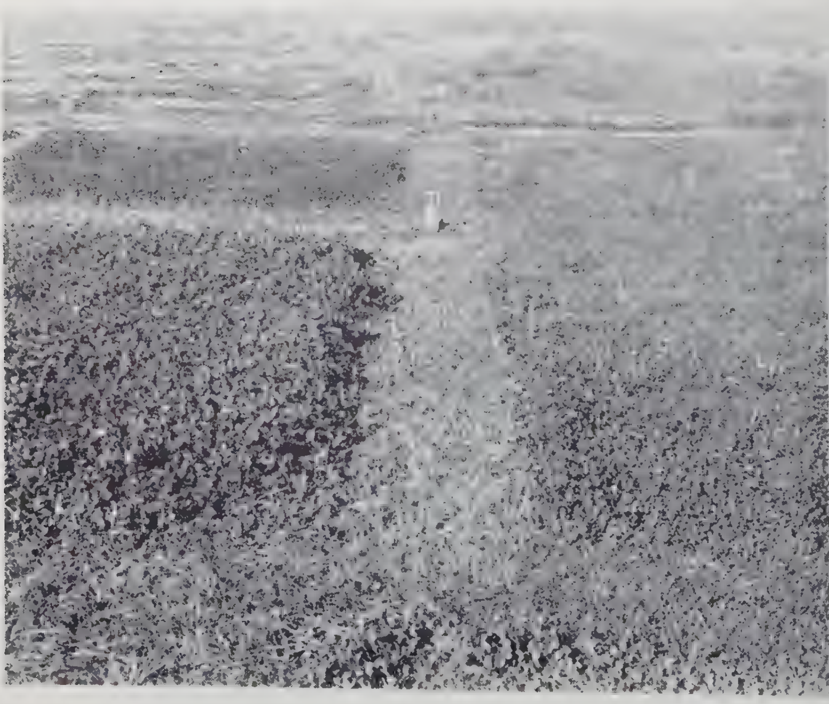

Figure 1.—Effect of lack of sulfur in the fertilizer program for White Dutch clover and Pensacola Bahia grass on plots of Rutledge fine sand of the Florida flatwoods. Photographed January 8. Plots at upper and lower right received a heat-treated calcined phosphate lacking in sulfur. Lower left is the same treatment with gypsum added. Ordinary superphosphate was used in upper left. All plots received adequate amounts of potash, minor elements and lime.

In results so far obtained on the finer textured soils of West Florida (Tifton and Carnegie fine sandy loams), there was a definite response to gypsum when a sulfur-free calcined (dicalcium) phosphate was the source of phosphorus. The need for sulfur was not nearly so marked, however, as is the case for the sands and fine sands of peninsular Florida (Table 1). In the rock phosphate treatments for West Florida, phosphorus as well as sulfur probably operated as limiting factors.

Figure 2.—Effect of lack of sulfur as shown by four more plots of the same group as for Figure 1. The upper and lower plots at the left received rock phosphate for the source of phosphorus. Treatment was identical for the plot at lower right except that gypsum was added to equal that carried in the superphosphate of the upper right hand plot.

ROLE OF SUPERPHOSPHATE

Ordinary superphosphate is about one-half calcium sulfate by weight; this changes to hydrated gypsum soon after incorporation in the soil. Gypsum is a good source of sulfur, but it differs from the phosphate portion of the superphosphate in that it leaches readily from the soil. When ordinary superphosphate is used in the fertilizer mixture to supply phosphorus and gypsum, the problem becomes one of determining not only how much but how often superphosphate should be applied to maintain sufficient supplies of sulfur and phosphorus for a particular soil and crop. In this concept the problem broadens to include all crops, both legumes and non-legumes; for there is some experimental evidence indicating that all crops would soon be retarded in growth throughout much of Florida if they were not supplied with a source of sulfur such as is carried in ordinary superphosphate.

In recent years the problem of sulfur nutrition has been magnified by the growing tendency to use phosphates and other fertilizer ingredients that do not contain sulfur. Thus, rock phosphate and waste pond phosphate have been found to serve well as sources of phosphorus for pastures on the acid sandy soils of peninsular Florida. Muriate of potash has taken the place of sulfate of potash. Ammonia and ammonium nitrate have largely replaced ammonium sulfate. Sulfur-free concentrated superphosphate will come into wider use because manufacturing processes are to be geared to those that recover the uranium of the phosphate deposits of Florida.

The well-known world-wide shortage of sulfur has accelerated these trends toward fertilizer mixtures free of, or low in, sulfur. Even if the shortage of sulfur were alleviated somewhat, various factors will probably continue to reduce the amount of sulfur carried in a mixture. Thus, formulation of more concentrated mitxures is likely to increase; thereby decreasing the costs of bagging and transporting a more bulky, heavier product. Phosphates processed by heat instead of sulfuric acid are known to be good types of phosphorus for Florida. If a cheaper source of heat, as for instance, from oil or gas, becomes available in Florida, the production of heat-treated phosphates might increase. Should that be the case it would add to the several other causes leading to the reduction of sulfur in fertilizers.

These gradual changes in the composition of a fertilizer mixture are liable to creep up unawares, so that a farmer may be using a sulfur-deficient mixture without realizing that a sulfur deficiency is causing a decrease in crop yields. This danger is not limited to Florida alone. It could occur—and doubtless is occurring—in several of the southern and eastern states where the easily soluble sulfate is lost from the soil by leaching in excess of that supplied by soil organic matter, manures and rainfall.

Back of the farmer is the extension specialist, who may forget or be unaware that sulfur is leaching in the soil management program that he is recommending to the farmer. Back of the extension specialist is the research worker and back of him is the wall of the unknown. The research worker should be especially alert to the possibility of lack of sulfur in his experimentation relative to efficient production. He is the safety man, so to speak, and if he muffs the ball or fails to see it because of the fog of ignorance that may surround him, the consequences could be unfortunate.

CONCLUSION

In conclusion, a critical situation exists relative to the proper fertilizer program for pastures growing legumes. Over much of the state, soluble nutrients leach readily from the soils of these pastures. The sulfate ion is almost as mobile as the nitrate. Thus a sulfur deficiency is likely to occur rather quickly for legumes, since they require about as much sulfar as phosphorus. For a legume-grass pasture, a deficiency of sulfur is much more likely to occur than a deficiency of nitrogen, since the fixation of atmospheric nitrogen by the legume bacteria causes a gradual release of nitrogen in soluble form in the decaying roots.

For reasons mentioned, there may be an ever-increasing tendency toward the use of sulfur-free phosphates and other plant food carriers in the fertilizer mixture. It, therefore, behooves the research worker to obtain in advance the fundamental information that may be needed to cope with the soil management and fertilizer situation of the future. For, as is well known, the obtaining of that type of information takes time. It cannot be produced on the spur of the moment of need.

In an attempt to anticipate these needs a research project on sulfur has been set up in the Department of Soils in which several research workers of the Florida Experiment Station system are participating. We would be glad to have the cooperation of others and any suggestions relating to the problem.

PASTURE INSECTS AND THEIR CONTROL

L. C. KUITERT and A. N. TISSOT*

INTRODUCTION

Expansion of the Improved Pasture program in Florida has brought with it several entomological problems. Entomologists of the Florida Agricultural Experiment Station are of the opinion that the future of the insect picture has but one course; it will increase in importance! As the pasture acreage increases the insect problem increases. As the fertilization program expands the insect program expands. As the rancher becomes more and more dependent on pastures he will want to institute better insect control methods. Because of these and other reasons a research project has been established by the Experiment Station on, "The Control of Insect and Related Pests of Pastures". The object of this project is, "To determine what insects and related animals are pests or potential pests of pastures in Florida and to devise effective, safe and economical means of control."

Comparatively little research has been done on pastures anywhere, other than grasshopper control in the West. The pasture insect control work to date has involved the control of the fall armyworm, the grassworm, yellow sugar cane aphid and mites.

PREVIOUS WORK

For the past several years we have been receiving reports of damage to pastures by armyworms from various sections of the state. The trouble appeared to be more common in Pangolagrass pastures where the cattle had been taken off and the grass allowed to grow for winter grazing. Although these pasture pests were commonly referred to as armyworms, it seems certain that at least two species of insects were involved. There is evidence that the fall armyworm, *Laphygma frugiperda* (A. & S.), was responsible for some of the damage but in many instances where specimens were sent in for identification, or where good descriptions were given, the insects were grassworms, *Mocis repanda* (F.). It is possible that one or more species of sod webworm also may have been responsible for some of the damage.

An appreciable amount of work has been done on the control of grasshoppers in the state. Griffiths et al (1) have published their findings on the control of grasshoppers in citrus groves. Connin and Kuitert (2) have published their results on the control of the American grasshopper. Although these workers restricted their efforts to controlling these insects in citrus groves, corn and peanuts it is assumed that their recommendations would be effective in controlling grasshopper infestations in pastures.

LEPIDOPTEROUS LARVAE.—Very little information is available on the control of lepidopterous larvae infesting pastures. A small-plot test was

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made during June of 1950 in a field of Bermuda grass heavily infested with fall armyworms. The insecticides used were parathion 1%, methoxychlor 5%, DDT 3%, rhothane 3%, and toxaphene 5% dusts. A rotary type hand duster was used to apply the insecticides. For a few days after treatment numerous dead larvae were found in the toxaphene plots and smaller numbers in the parathion plots. Observations also indicated that the dead and moribund larvae were being eaten by the unaffected larvae. The percentage of control could not be determined as larvae migrated into the test plots from adjacent areas. A week after treatment the grass in the toxaphene plots was putting out new growth and showed marked improvement over the untreated check. The DDT and rhothane treatments were intermediate between toxaphene and the other two treatments, which were only slightly better than the checks.

In a second test, parathion and toxaphene were applied to one- and two-acre plots in a field of millet heavily infested with fall armyworms. The parathion was applied as a 1% dust at rates of 14 and 20 pounds per acre and toxaphene 5% dust was applied at 24 pounds per acre. The insecticides were applied with a four row duster mounted on a tractor. For several days after application numerous dead larvae were found in the toxaphene plots and after a week the millet in these plots showed great improvement over that in the parathion plots, which were only slightly better than the untreated checks.

GRASSHOPPERS.—Grasshoppers have been an annual problem. In recent years there have been numerous reports of destruction of corn, peanuts, oats and pasture grasses. Extensive damage to the seed heads of Pensacola Bahiagrass has been reported. Tests were made in November 1950 to determine the effectiveness of insecticides against adult American grasshoppers *Schistocerca americana* Drury. All materials tested were used as emulsions. The materials used and the rates of application, based on active ingredients per acre, were aldrin at 2, 4, and 8 ounces; chlordane at 1 pound; and toxaphene at 1.5 pounds. It was impossible to evaluate the results accurately as the grasshoppers moved about so freely. All of the materials killed some grasshoppers; however the tests showed it was impractical to attempt to control the American grasshopper in the adult stage.

Tests were begun in the spring of 1951 in cooperation with R. V. Connin of the Bureau of Entomology and Plant Quarantine to determine the effectiveness of insecticides for controlling immature stages of the American grasshopper and all stages of the red-legged grasshopper *Melanoplus femur-rubrum propinquus* Scudd.

Several series of replicated tests were performed. Plots used were 0.1, 0.4, 0.8, and 1.0 acre in size. Insecticides were applied to the small plots with hand equipment and to the large plots with a Yellow-Devil, high-concentration, low-gallonage row-crop sprayer mounted on a USDA power wagon. The following rates of application used are based on the amount of active ingredients per acre. Dusts applied to the small plots were 2.5% aldrin at 0.625 and 0.225 pounds; 10% toxaphene at 3.5 and 2.5 pounds; 5% chlordane at 1.3 pounds; 2% parathion at 0.4 and 0.6 pounds; 1% parathion at 0.25 pounds and 3% lindane at 0.78 pounds. Emulsion concentrates applied as sprays to small plots were dieldrin at 1.5 ounces, aldrin at 5 ounces and heptachlor at 4 ounces. All treat-

ments gave satisfactory control with mortalities of 90% or higher in 3 days and 88% or higher in 5 days with the exception of the lindane and 1% parathion treatments.

Only emulsion concentrate sprays were applied to the large plots. The insecticides used and the rates of application based on active ingredients per acre were dieldrin at 1.5 ounces, heptachlor at 2 ounces, aldrin at 2 and 4 ounces, chlordane at 1 pound, toxaphene at 1.5 pounds and lindane at 0.5 pound. With the exception of lindane all materials gave mortalities of 94 per cent or higher in three days, and 93 per cent or higher in five days.

APHIDS.—Aphids are serious pests of Pangolagrass. The aphid of greatest importance is the yellow sugar cane aphid *Sipha flava* (Forbes). At present parathion is recommended for aphid control. This recommendation is based on information obtained in tests made on vegetables and other crops. Tests should be made to evaluate insecticidal control of aphids infesting the pasture grasses and winter pastures. Several new phosphatic insecticides are now undergoing tests to determine their effectiveness in controlling aphids. One of these, malathon, appears to have considerable promise.

CLOVER MITES.—During recent years there has been a trend toward the use of clover for winter pastures. For the past two years we have observed serious damage by clover mites to the clovers, especially white clover. No attempt was made to evaluate the seriousness of these mite infestations, but damage was severe in a number of instances. On several occasions the death of many plants was attributed to the mites.

A number of small tests were made early in 1952 to evaluate the effectiveness of some miticides in controlling these pests. The first tests were superimposed over plots used by the Soils Department. The plots were 1/35 acre in size and 3 gallons of spray were applied to each plot, using a 3-gallon pneumatic sprayer. The treatments were replicated three times. The two treatments used were parathion 15 per cent wettable powder plus ovotran 50 per cent wettable, each used at one pound per 100 gallons and Systox 32.1 per cent used at one quart per 100 gallons. No attempt was made to obtain pretreatment counts as many of the mites would drop off of the leaf when it was picked. Two days after treatment a number of leaves were picked at random in each plot. A composite sample of each treatment was made. Counts were made of the living and dead mites found on 25 leaves from each treatment. The results were as follows:

RESULTS OF COUNTS MADE TWO DAYS AFTER TREATMENT

Treatment	Mites	Dead	No. of Leaves with Live Mites
Check	41	21	17
Systox	0	159	0
Parathion and ovotran	2	62	1

Results of Counts Made 11 Days After Treatment

Treatment	Mites	Dead	No. of Leaves with Live Mites
Check	101	25	25
Systox	1	161	1
Parathion and ovotran	4	41	3

Subsequent observations made during the following two months indicated that the new foliage remained free of mite infestations suggesting that a single application may so reduce the population that further treatment would not be necessary.

In a second series of tests the plots were established in areas heavily infested with mites. The mites had caused extensive damage to a large percentage of the leaves and it was estimated that more than 50 mites were present on each leaf. The plots were 1/100 acre in size and one gallon of finished spray was applied to each plot. Provision was made for five treatments and a check replicated three times. The insecticides were applied by means of a 3-gallon pneumatic sprayer.

The following materials were used at the rates indicated:

EPN Miticide 31.5% active (duPont) 1 lb./100
Aramite 15% W. P. (U. S. Rubber) 1 lb./100
Systox 50% emulsion (Chem-Agra) 1 qt./100
B. P. Miticide 95% emulsion (duPont) 1 qt./100
Parathion 1 lb. 15% W. P. plus ovotran 1 lb./100

Counts of mites were made eight days after treatment. Some 10 to 15 leaves were picked at random from each of the three plots for each treatment. Counts of living mites were made on 10 of the leaves from each treatment with these results:

Number of Living Mites per Leaf

Materials	1	2	3	4	5	6	7	8	9	10	Total
EPN	60	22	36	18	27	32	29	18	24	18	284
B. P. Miticide	0	1	6	1	3	0	1	3	1	0	16
Check	16	31	22	22	11	6	12	11	5	6	142
Parathion-ovotran	3	1	5	5	9	2	3	1	3	3	35
Systox	0	0	1	0	0	1	0	0	0	0	2
Aramite	18	10	20	22	15	8	11	52	29	24	218

Observations were made several times during the next two months. During this time the foliage in the plots treated with the effective materials remained practically free of mites. Only occasional infestations

were found on the new foliage in the better treatments while many plants were killed in the check and poor treatments.

POTENTIAL PROBLEMS

During the summer and fall of 1952 a number of surveys were made involving the insect pests and other animals infesting the grasses in lawns and recreational areas.

CHINCH BUGS.—These insects, *Blissus leucopterous insularis* Barber, were found to be doing extensive damage to St. Augustine grass lawns throughout the state. Although some investigations have been made on the control of this pest further testing is necessary. We have not received any reports of chinch bugs damaging any of the St. Augustine grass pastures.

SCALE INSECTS.—We have had requests for information regarding the importance of these insects when infesting pasture grasses. Three species of scales are involved: Rhodes scale, *Antonina graminis* (Mask.), Bermuda grass Odonaspis, *Odonaspis ruthae* Kotinsky, and ground pearls, *Eumargarodes laingi* Jak. The common names of the first two species indicate the only host plants on which they have been found while the ground pearls have been found on Bermuda grass, natal grass, and maiden cane grass. Observations indicate that under adverse conditions these insects are definitely responsible for killing the grass. No effective treatment has been found for controlling these scales.

LEAFHOPPERS.—In general, entomologists have not concerned themselves with leafhoppers infesting pasture grasses since their damage is not spectacular like that caused by the chewing insects. Many species of leafhoppers feed on grasses. They are sucking insects and are frequently extremely numerous. It is the opinion of the writer that leafhopper damage is more important than that implied in the literature.

SUBTERRANEAN INSECTS.—Very little is known concerning the role of mole crickets, cutworms and wireworms infesting pastures. Investigations must be undertaken to determine the various species, their distribution, their prevalence, and their destructiveness to pasture herbage. Control measures must be developed for those species of economic importance.

REFERENCES

1. Griffiths, J. T., and W. L. Thompson. Grasshoppers in citrus groves. Fla. Agric. Expt. Sta. Bul. 496, 1952.
2. Connin, R. V., and L. C. Kuitert. Control of the American grasshopper with organic insecticides in Florida. Jour. Econ. Ent., 45:no. 4, 684-687, 1952.

A METHOD OF DETERMINING THE AMOUNT OF MONEY A FARMER CAN INVEST IN IMPROVED PASTURES

W. K. McPherson and L. A. Reuss*

INTRODUCTION

During the last fifteen years, improved pastures have been established on from 7 to 12 per cent of the farm land in Florida. Estimates of the acreage of improved pastures in the state now vary from 1.2 to 2 million acres and represent an investment of from 30 to 50 million dollars.[1]

In many respects pasture improvement was a speculative investment fifteen years ago. At that time relatively little was known about how to build pastures, or about the productivity of improved pastures once they were built. Since then numerous researches have been conducted on pasture improvement, and the results of these researches have been augmented by the experience of farmers who pioneered pasture development. Of course, the full impact of pasture improvement on Florida agriculture will not be known for many years. Nevertheless, results to date are promising enough to stimulate the interest of almost every farmer in the State, as well as many investors living in other parts of the country.

Those who have already invested in improved pastures expect them to earn a reasonable return over a span of five, ten, or twenty years—a return that will be comparable to the return that they might have earned by investing the same amount of money in some other enterprise. If their judgment is correct, the development of more improved pastures in Florida constitutes a major economic opportunity. For every acre that has been improved to date there are at least five more that can be converted into improved pastures.

Those who are interested in improving pastures but have not yet done so, are seeking more convincing evidence that the returns will be large enough to make the investment attractive. They are seeking information from the Agricultural Experiment Stations on how to build pastures. They are trying to find how much it costs to improve pastures. They are asking their neighbors how much beef an improved pasture will produce. In other words, they are seeking a logical basis for deciding whether or not to invest money building pasture land.

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The authors gratefully acknowledge the suggestions and constructive criticism of H. G. Hamilton, R. E. L. Greene, T. J. Cunha, G. B. Killinger, and Nathan Gammon, Jr., Agricultural Experiment Station, Gainesville, Fla.

[1] This estimate is based on the assumption that the average cost of this pasture improvement has been \$25 per acre. There is no way of determining precisely how much of this investment was made from private accumulation and how much was made from funds received as P.M.A. payments.

Florida Agricultural Experiment Station Journal Series, No. 135.

The viewpoints expressed herein do not necessarily represent those of the B.A.E.

PURPOSE

The purpose of this paper is (1) to identify the factors that establish the value of improved pasture land, and (2) to show how this value sets the upper limit on how much a farmer can invest in pasture improvement. To do this, a model is used to illustrate the method of evaluating pasture improvement on any particular tract of land.

AN INVESTMENT IN PASTURE IMPROVEMENT IS AN INVESTMENT IN LAND

The first step in the analysis is to establish the fact that an investment in improved pastures is essentially the same kind of an investment as the purchase of a tract of land. This concept is relatively simple; but when carefully analyzed and placed in the perspective of time, it has special significance in Florida.

Agricultural land is an arrangement of the components of the natural environment that will produce the kind of plants and animals human beings want to consume. These natural components are subsoil, soil, plant nutrients, topography, flora, water and climate (sunlight and temperature).

When the population of the earth was small, all components of the natural environment were plentiful, and people used them freely to satisfy their many wants and desires. The only limitation on the use of land was the technical knowledge available, the energy to apply this technology, and the need for food and fiber.

The discovery of North America included the discovery of many combinations of the several components of the natural environment that would produce agricultural products when the technology available at the time was applied. This was especially true in the Midwest, where pastures and cereal grains could be produced, and in the South for the production of cotton and tobacco. Combinations of the natural environment that would produce citrus were found in California, Florida, and Texas.

To maximize the productivity of this land, the English institution of private property was employed and later incorporated in the constitution of the nation. Since then, this institution has been refined and extended to meet the needs of an expanding economy. As long as the components of nature that were needed to produce agricultural products could be found in one location, the process by which an individual could acquire agricultural land was relatively simple—all that was necessary was to arrange for a transfer of title at a price agreed upon by buyer and seller.

As population and hence demand for food and fiber increased, those combinations of the components of nature that would produce agricultural commodities became increasingly scarce and hence acquired economic value. At the same time, new methods of utilizing the components of nature to increase the production of agricultural commodities were developed. Now, in the middle of the 20th century, sufficient technology has been developed to enable people to assemble the components of the natural environment in one place and to arrange them in a manner that will produce more agricultural commodities than could be produced on the natural agricultural land found in this country by the colonists.

In this perspective, the development of pastures in Florida is essentially a land-building project. The natural arrangement of the several components of agricultural land in Florida is not as productive as the natural arrangement of subsoil, soil, plant nutrients, topography, flora, water, and climate in other parts of the country. However, these components of nature are quite readily available in the State, and it is possible to arrange them to produce very large quantities of grass—in some instances, larger quantities than can be produced on natural land. Thus, the value of Florida land for agricultural purposes can be expected to rise in the long run if the demand for food and fiber continues to increase. Demand for food and fiber will increase as (1) population increases, and (2) per capita income increases. However, there is always the possibility that changes in technology will alter the comparative advantages and depress the value of land used for specific enterprises.

Throughout the nation returns per acre from production of forage for beef animals are generally less than returns from the production of cereal grains, cotton, tobacco, citrus, and vegetables. Consequently land that will not enable growers to earn attractive returns from the production of these crops is used for beef production. This is the reason a large proportion of the stocker and feeder beef animals are raised on the arid range lands of the west. Producers of beef cattle in Florida, are, in effect, competing with the western ranchers. Whether Florida ranchers can compete successfully with ranchers using western range lands depends upon whether they can produce grass-fed animals at a lower cost per pound, or at a cost below the national equilibrium price of these animals.[2] Among other things, the cost of producing grass-fed animals depends upon the value of the land used to produce forage.

The climate of Florida is especially favorable for production of pasture forage, since it provides a long growing season and an abundance of sunshine. To make full use of climatic conditions, it has been necessary to develop new varieties of plants and to control insects and parasites. Although the soil does not provide adequate plant nutrients for growth of pasture plants, it does provide an excellent medium for feeding plants with commercial fertilizer. This is becoming more important as natural soil nutrients are depleted in other parts of the nation. Rain falls in sufficient quantities to provide the water needed for growth of pasture plants, but the uneven distribution of this water throughout the year reduces the productivity of pastures. This can be offset by drainage and/or irrigation, since the water table is relatively high and the topography of the soil relatively flat. The question is, Will the returns justify the cost of building pastures?

FACTORS THAT DETERMINE THE VALUE OF IMPROVED PASTURES

In as much as the primary objective of building improved pasture land in Florida is to produce forage for beef animals, this analysis is confined to identifying the factors that determine the value of pastures used for this purpose. Consequently, this method of determining the value of pasture land cannot be used to determine the value of a farm.

[2] If Florida ranchers cannot produce beef at a lower cost per pound than western ranchers, they will be among the first to be forced out of the industry if the price level falls.

However, with appropriate data, this method can be used to determine the value of pastures used to produce forage for milk cows or sheep.

Productivity is the first factor that must be considered. When pastures are used to produce beef, the best measure of their productivity is the quantity of beef that can be marketed per acre. Within a given climate the production capabilities of land are largely determined by type of soil, response of that soil to application of fertilizer, and amount of water available.[3] The type of soil upon which an improved pasture is built generally affects productivity more than geographic location. Florida has many types of soil, and they are widely distributed throughout the 67 counties. In fact, there are several types in each county and often on each farm.

On a given type of soil, productivity of pastures varies widely with the number and variety of pasture plants per acre. Obviously, more pasture plants can be grown on an acre of land that is cleared than when trees or other plants compete for plant nutrients. For this reason the more productive pastures are those cleared of trees, palmettos, and other vegetation. The effect of the variety of pasture plants on the productivity of pastures is best illustrated by research that shows native carpet grass producing 64 pounds of beef per acre, and pangola producing 166 pounds at the same level of fertilization.[4]

Holding soil, the variety of pasture plants, and fertilization constant, the productivity of a pasture depends upon availability of the proper amount of water throughout the growing season. In most instances, farmers depend upon the incidence of rainfall, topography, and type of soil to make water available in the correct amounts. Frequently, this injects considerable risk into the level of productivity of a pasture.

To produce any specified quantity of beef per acre on a given tract of pasture land, it is often necessary to make several kinds of investments. These include (1) acquisition of a title to the tract,[5] (2) clearing, (3) leveling,[6] (4) drainage and/or irrigation facilities, and (5) establishment of pasture grasses. Once these investments are made, the improved pasture land will produce at rates that management can vary between limits in accord with current economic conditions. The question that interests most farmers is, How much money can be invested in these five components of pasture land?

The variable cost of producing the grass to attain various levels of productivity is the second factor that enters into the value of improved pastures. Variable costs include: fertilizer, controlling water,[7] maintaining fences, supplying mineral supplements for animals, interest on capital invested in livestock,[8] labor,[8] and management.[8] Altering productivity

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[3] Temperature and the amount of sunshine affect productivity of pastures; but since they cannot be altered, they are considered as natural risks in this analysis.

[4] Hodges, E. M., D. W. Jones and W. G. Kirk. "Grass Pastures in Florida." *Florida Agricultural Experiment Station Bulletin 484*, 1951. Average beef gain per acre per year made by yearling and two-year-old steers grazing limed and fertilized (500 pounds 6-6-6 per acre applied in spring of each year) pasture during spring and summer, 1945-49.

[5] Or, the right to use the land on a long-time lease or contract.

[6] Altering topography to improve drainage, to make possible the control of the water table, or to facilitate the use of machinery.

[7] Both drainage and irrigation as well as providing drinking water for the stock.

[8] These are questionable items of cost when returns to these factors constitute income rather than expense to the owner. (See page 142.)

by varying the amount of labor and capital applied to pastures provides one means by which farmers can maximize returns when the price of beef rises or falls. Fertilizer is generally the largest single item of variable cost in making improved pastures productive in Florida.[9] Hence, altering the amount of fertilizer applied provides the most effective mean of controlling production.

The long-run price of beef is the third factor that enters into the value of improved pastures. Estimates of the long-run price of beef are, at best, difficult to make with any degree of accuracy, because each of the several factors that influence the price of beef is outside the control of any one individual. Such things as rate of increase in the population of the nation, changes in amount of disposable income, changes in the value of currency, shifts in consumers' preferences for beef, and availability of other meats, all influence the demand for beef. Since price is a function of supply as well as demand, the long-run price is also influenced by what other livestock producers are doing. Potential investors in pasture land tend to use relatively low price levels in planning their enterprises in order to protect themselves against violent short-run price fluctuations. It is fairly clear that, in the long run, the demand for meat and all other foods will increase because of the increase in population; but short-run fluctuations in the level of economic activity may depress prices for periods of several years.

The price of beef can be distinguished from the efficiency with which capital and labor are employed in beef enterprises, as one of the factors that alters economic value of improved pastures. Returns to capital and labor in a beef enterprise, at any given level of prices, are largely a product of management. For this reason an average level of management must be assumed in determining an average level of economic value of pasture land. The ability of management to earn higher than average returns to labor and capital by using more efficient production practices does not affect the value of land to another entrepreneur. The fact that one management of a beef enterprise can make a tract of improved pasture earn more money than another does not increase the value of the improved pasture in the land market. Instead, it simply increases the returns to management. The value of improved pastures in the land market[10] is determined by what all entrepreneurs believe they can earn in the beef industry at the average level of prices they expect to prevail for beef in the future, and with average management.

A METHOD OF ESTIMATING THE VALUE OF IMPROVED PASTURES

To estimate the value of an improved pasture, values must be placed on productivity, variable costs, and the level of beef prices. This is a task each entrepreneur must do for himself in an enterprise economy.

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[9] Water control is frequently an exception. In some other parts of the country the cost of water is much larger than the cost of fertilizer. It is conceivable that this will be true in Florida if the demand for agricultural products increases as much in the next century as it has in the past.

[10] The land market for improved pastures *per se* is limited. Generally, land is sold in tracts that include improved pastures, and the value of these pastures is averaged with the value of other land.

Characteristics of soils and availability of water vary so widely that the potential range of productivity and the variable costs of attaining these productivities vary from farm to farm. Each farmer bases his estimates on his own experience insofar as possible. Consequently, the level of management assumed in each case is different, and different farmers may place different values on the same pastures under the same level of beef prices. Then too, different entrepreneurs may have different ideas of the level of beef prices in the future.

The following example serves the dual purpose of illustrating the type of estimates that must be made and how these estimates can be used in establishing the upper limit of pasture land investments in terms of dollars and cents.

(1) Assume five levels of productivity.[11]

(a) 15 pounds of marketable beef per acre. This might be attained on native pastures without fertilization.

(b) 50 pounds of marketable beef per acre. This is well above the productivity of unfertilized native pastures, but is relatively low in comparison with the volume of beef reported to have been produced on a number of experimental plots with moderate fertilizer application.

(c) 150 pounds of marketable beef per acre. 150 pounds of beef is an average production that might be attained with improved management practices on some flatwood soils and is considerably above the state average.

(d) 400 pounds of marketable beef per acre. This relatively high level of productivity has been attained on a number of experimental pastures, and it is possible that it can be attained on better soils with considerable regularity.

(e) 600 pounds of marketable beef per acre. This high level of productivity might be attained on especially good soil but at a considerable increase in variable costs.

(2) Assume the variable costs [12] of maintaining pastures at the above levels of productivity, as follows:

(a) $1.50 per acre.
(b) $6.00 per acre.
(c) $16.00 per acre.
(d) $42.00 per acre.
(e) $75.00 per acre.

Variable costs may vary widely for different soil types, water conditions, etc. These assumed costs might approximate those incurred on improved pastures requiring fertilization but little or no water control. When water is controlled on the scale used south of Lake Okeechobee, the variable costs may be much higher. In the northern part of Florida, where legumes can be readily grown, variable costs may be lower for comparable levels of productivity.

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[11] This number may vary. It is desirable to assume as many levels of productivity as possible with the data that can be obtained.

[12] See page 136.

(3) Assume the long-run price of grass-fed beef animals at three levels:

(a) A low price of $8.00 per cwt.

(b) A price of $13.00 per cwt. which might prevail the next few years.

(c) A price of $18.00 per cwt., representing a conservative estimate of the average price of grass-fed animals since World War II.

This assumption implies that a return to management may be earned in raising feeders. or buying feeders and selling grass-fed animals. As pointed out earlier, the variable cost estimates include only a nominal labor and management return for the time the animals are fattened on pasture. Net returns per acre under the various combinations of these assumptions are presented in Table 1.

TABLE 1.—NET RETURNS FROM IMPROVED PASTURES UNDER ASSUMED LEVELS OF PRODUCTIVITY, VARIABLE COSTS, AND BEEF PRICES

Production Lbs. Beef per Acre		Variable Costs*	Gross Returns per Acre at $8.00 CWT.	$13.00 CWT.	$18.00 CWT.	Net Returns per Acre at $8.00 CWT.	$13.00 CWT.	$18.00 CWT.
A	15	$ 1.50	$ 1.20	$ 1.95	$ 2.70	—$ 0.30	$ 0.45	$ 1.20
B	50	6.00	4.00	6.50	9.00	— 2.00	0.50	3.00
C	150	16.00	12.00	19.50	27.00	— 4.00	3.50	11.00
D	400	42.00	32.00	52.00	72.00	— 10.00	10.00	30.00
E	600	75.00	48 00	78.00	103 00	— 27.00	3.00	33.00

* For purposes of simplifying these illustrations, it is assumed that feeder cattle are purchased and that the purchase cost would be the same as the cost, including management, of raising feeders on the ranch.

From these data it is possible to estimate the economic value of improved pastures at various levels of production, assumed variable costs, and beef prices. This is done by capitalizing the returns as demonstrated in Table 2. If the risk in cattle production was comparable to the risk incurred in certain railroads, public utilities, and manufacturing firms, the return might be capitalized at 5 per cent. In other words, the investment in land would be amortized in 20 years. However, risk in the cattle industry is known to be relatively high, and for this reason a 20 per cent rate of capitalization or a 5-year amortization period is more realistic.

Here it should be noted that the variable costs of attaining each of the five levels of productivity are held constant while the price of beef is varied from $8 to $18. Variable costs tend to fluctuate with beef prices, but perhaps not as violently. If the variable costs presented approximate the costs incurred at the $13 level of beef prices, the values of land indicated in Table 2 at the $8 beef price level are somewhat low; and at the $18 level, somewhat high.

Among other things, the data in Tables 1 and 2 indicate under these assumptions that (1) the level of productivity is a major element in

determining the value of improved pastures (compare cases A and D), (2) the level of beef prices has an important impact on pasture values (compare value at the three price levels), and (3) the point of maximum net returns changes with the price level (when cases D and E are compared, the value of land in case E decreases at the $13 level and increases at the $18 price level).

The values in Table 2 are the upper limits of the amount of money that it is desirable to invest in the acquisition of improved pastures. If the investor is confident that he can produce 600 pounds of beef per acre at a variable cost of $75, is sure beef prices will average $18 per cwt. over a 20-year period, and will be satisfied with a five per cent return on his investment, he can spend up to $660 per acre to acquire title to a tract of land and build a pasture. On the other hand, if an investor wants a twenty per cent return on his investment, can produce only 50 pounds of beef per acre at a variable cost of $6, and expects beef prices to average $13 per cwt., he can afford to pay only $2.50 per acre for title to land and the cost of pasture improvement. These extremes are cited to demonstrate a range in value of pastures under different assumed conditions.

TABLE 2.—MAXIMUM VALUE OF IMPROVED PAASTURES PER ACRE UNDER VARYING BEEF PRICES AND AMORTIZATION PERIODS*

	20-Year Amortization (5 Per Cent Capitalization)			5-Year Amortization (20 Per Cent Capitalization)		
	$8 Price Level	$13 Price Level	$18 Price Level	$8 Price Level	$13 Price Level	$18 Price Level
A	—$ 6.00	$ 9.00	$ 24.00	—$ 1.50	$ 2.25	$ 6.00
B	— 40.00	10.00	60.00	— 10.00	2.50	15.00
C	— 80.00	70.00	220.00	— 20.00	17.50	55.00
D	— 200.00	200.00	600.00	— 50.00	50.00	150.00
E	— 540.00	60.00	660.00	— 135.00	15.00	165.00

* Land values here are "economic" or "production" values and are not to be confused with "market" or "sale" values.

As pointed out earlier, it is necessary to keep three things in mind in estimating the value of pastures: (1) the value established is the value of land in pasture, not all the land in the farm; (2) the value established is for the beef enterprise only—perhaps values would be higher for producing milk or some other product; and (3) the value established is the upper limit for all permanent land improvements, including title, clearing, drainage, irrigation, seeding, etc. It must be recognized, however, that the actual rate of return that is earned on a particular investment is largely a function of management. One farmer can invest $200 an acre in land and make money, while another can invest the same amount in land of exactly the same quality and lose it all in five years. The value of pasture land is based on an average level of management and pasture values will rise and more land will be con-

verted to improved pastures as Florida farmers become more efficient producers of beef, so long as the price level is high enough to return a profit on beef production. Florida pastures are being improved by people with different objectives. In some instances, the objectives of the investors are reflected in their evaluation of productivity, variable costs, and price levels.

THREE OBJECTIVES OF INVESTING IN IMPROVED PASTURES

1. Land Development. Some entrepreneurs invest in pasture improvement to enhance the market value of native land. These investors endeavor to increase the productivity of land at a *minimum* cost and sell land at prices based on the productivity of the new land.

It is difficult to identify investors of this type because they are generally in position to hold the title until a purchaser is found. To do this, they establish a beef production enterprise. This enterprise may not be entirely efficient: but this is not of paramount importance to the investor, as he expects to make his profit on the sale of land rather than on beef. Consequently, the land developers are not as much interested in the rate of return on the investment as they are in the market price of pasture land. Farmers who are alert to any opportunity to sell land when prices are attractive also fall into this classification.

2. Beef Production. Other entrepreneurs invest in pasture improvement to establish an efficient beef production enterprise. Since beef production is an extensive enterprise, i.e., it uses large tracts of land and relatively small amounts of labor, the scale of operation is large when measured in terms of acres and dollars. The magnitude of such an enterprise can easily be calculated from the above model by assuming a production of 400 pounds of beef per acre. If the entrepreneur can earn one cent per pound for management, it will be necessary to produce 500,000 pounds of beef to earn a management income of $5,000 over and above the return to land. Twelve hundred and fifty acres of improved pastures would be required to produce this volume of beef; and if each animal gained 300 pounds a year on pasture forage, it would be necessary to stock the land with 1,666 animals. At $50 per acre this represents an investment of $62,500 in improved pasture land, $75,830 for feeder animals (making a total of $138,00), and an expenditure of $52,500 to cover variable costs in order to earn $12,500 as a net return to land. The variable costs above include allowances for labor, management and interest on capital invested in livestock. In this case, if the management return amounted to one cent per pound, as assumed above, the returns to the entrepreneur would be $5,000 over and above land returns.

It is highly doubtful whether a rancher would invest more than $50 an acre to acquire improved pasture for this enterprise, because of the market risk involved and the length of time required to amortize the cost of building land. Then, too, many ranchers find it necessary to borrow capital for pasture improvement. To obtain this type of loan, a borrower must show reasonably good prospects of earning a higher rate of return on the investment than the rate of interest on the loan.

3. General Farmers. Another group of farmers improve pastures in order to provide themselves with an opportunity to work with a high degree of job security and, at the same time, have considerable freedom

to manage their own labor in several enterprises. Farmers who are seeking this objective are more interested in employing capital to maximize total income from land, labor, and capital together, rather than to maximize the return on any one factor of production. This type of investor can minimize out-of-pocket cost of pasture improvement by using his own labor, and he is frequently able to avoid borrowing money. As the cash outlay for pasture improvement is low for this type of farmer, his primary interest is the effect of these pastures on the overall returns to the combination of land, labor, and capital he employs in the group of enterprises he manages. Frequently these overall returns are not as large as he could have earned by employing the same resources in other enterprises, but they are large enough to provide a family with a satisfactory level of living. The satisfactions that flow from occupation, security, and the freedom to select working hours are sufficient to compensate these farmers for the low rate of return on their investments.

SUMMARY

To demonstrate a method of determining the value of improved pastures, it has been shown that:

(1) Improving pastures is one type of land investment.

(2) The factors that influence the value per acre of improved pastures used in the beef enterprise are (a) the quantity of marketable beef produced, (b) the variable costs of producing forage, and (c) the level of beef prices.

(3) The value of the pastures is determined by capitalizing the net returns from the beef produced at a rate that will compensate the investor for the risk involved in beef production.

(4) The accuracy of each investor's estimates of production costs and beef prices will determine the returns that an investment in improved pastures will earn.

(5) Three types of investors improve pastures; i.e., land developers, ranchers, and general farmers.

DEPTH AND FREQUENCY OF SUPPLEMENTAL IRRIGATION OF PASTURES

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The use of supplemental irrigation on pastures has increased during the last few years. However, very little information is available concerning the fundamentals of supplemental irrigation of pastures in Florida. Before an irrigation program can be established, the relationship between soil moisture in the root zone and plant growth must be determined. Once this information is available, methods of determining when to irrigate may be applied with more validity. During the summer of 1951, a project was undertaken at Gainesville to determine the optimum depth to wet the soil and the frequency of water application for supplemental irrigation of pastures. The results obtained from this experiment during the first year are presented in this paper.

TABLE 1.—INCHES OF AVAILABLE WATER IN THE ARREDONDO LOAMY FINE SAND TO VARIOUS PROFILE DEPTHS AT FIELD CAPACITY AND AT SOIL MOISTURE TENSIONS OF 200 AND 800 CM OF WATER. THE TENSIONS FOR EACH PROFILE WERE MEASURED AT TENSIOMETER DEPTH INDICATED.

Soil Profile Depth	Tensiometer Depth	Available Water		
		At Field Capacity	At Soil Moisture Tension	
			200 cm	800 cm
Inches	Inches	Inches	Inches	Inches
0-6	3	0.48	0.26	0.08
0-12	9	1.00	0.50	0.18
0-18	15	1.41	0.70	0.18
0-24	21	1.86	0.84	0.09

PROCEDURE

The experiment was established on Arredondo loamy fine sand near Gainesville. The experimental design was a split plot, randomized block with four replications; irrigation treatments were the main plots, 20 x 20 ft. in size, and pasture species were the sub-plots, 10 x 10 ft. Annual white sweetclover or Hubam, white clover (southern strain), Argentine Bahiagrass and Pangolagrass were selected as representative pasture species.

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Florida Agricultural Experiment Station Journal Series, No. 164.

The grasses were planted vegetatively in August, and the clovers seeded in November. One ton of lime and 600 pounds of 2-10-10 fertilizer per acre were applied to the soil surface prior to establishment of the grasses. Three additional applications of an 0-10-10 analysis at the rate of 800 pounds per acre were applied in November, February and June.

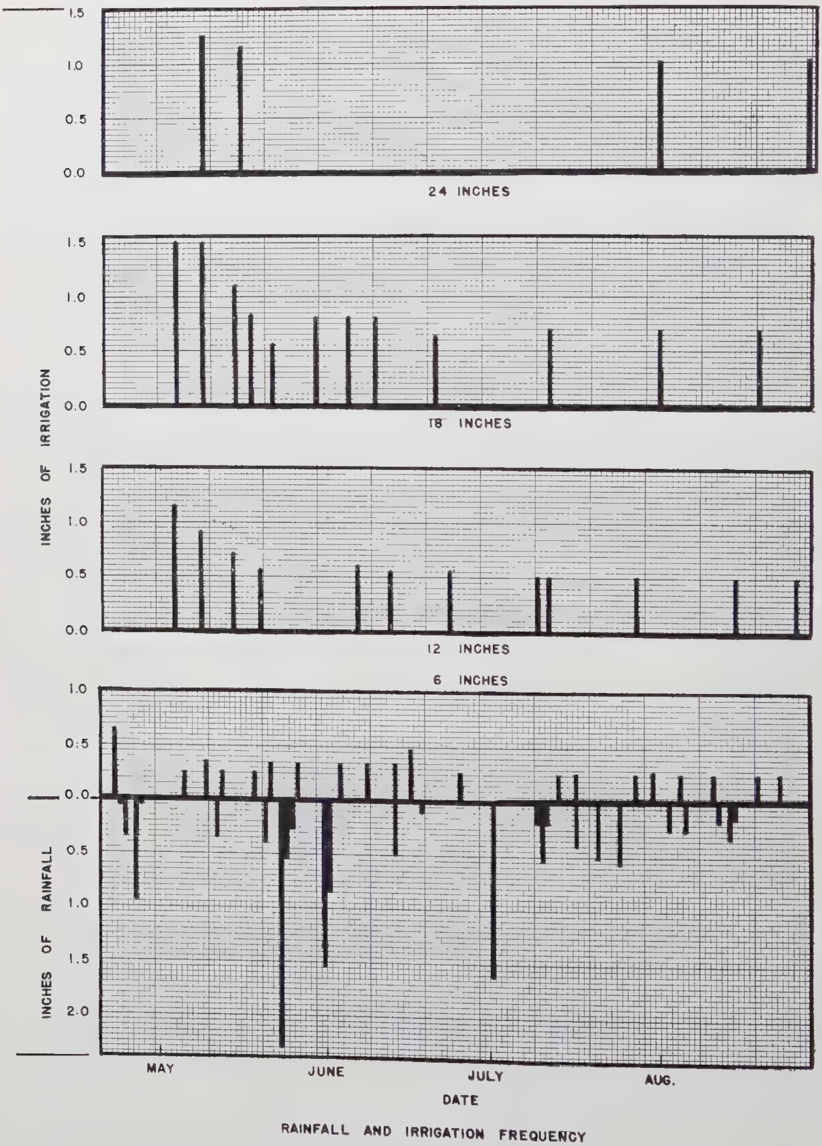


Figure 1.—Rainfall and irrigation distribution for the four depths of wetting when maximum tension schedule was 200 centimeters of water.

Nitrogen was applied to the grass at 50 and 150 pounds per acre of ammonium nitrate in June and August, 1952, respectively.

Two soil moisture ranges at four depths, and a non-irrigated treatment constituted the nine main plots. The two soil moisture ranges, high and medium, were maintained by irrigating when the soil moisture tension reached 200 cm and 800 cm water, respectively. The quantities of available water at field capacity, and at 200 and 800 cms tension at the four depths, are given in Table 1. At the 200 cm tension approximately 50% of the available soil moisture remained, while at the 800 cm tension about 15% remained. The depths of irrigation water applied to return the soil to field capacity can readily be calculated from Table 1.

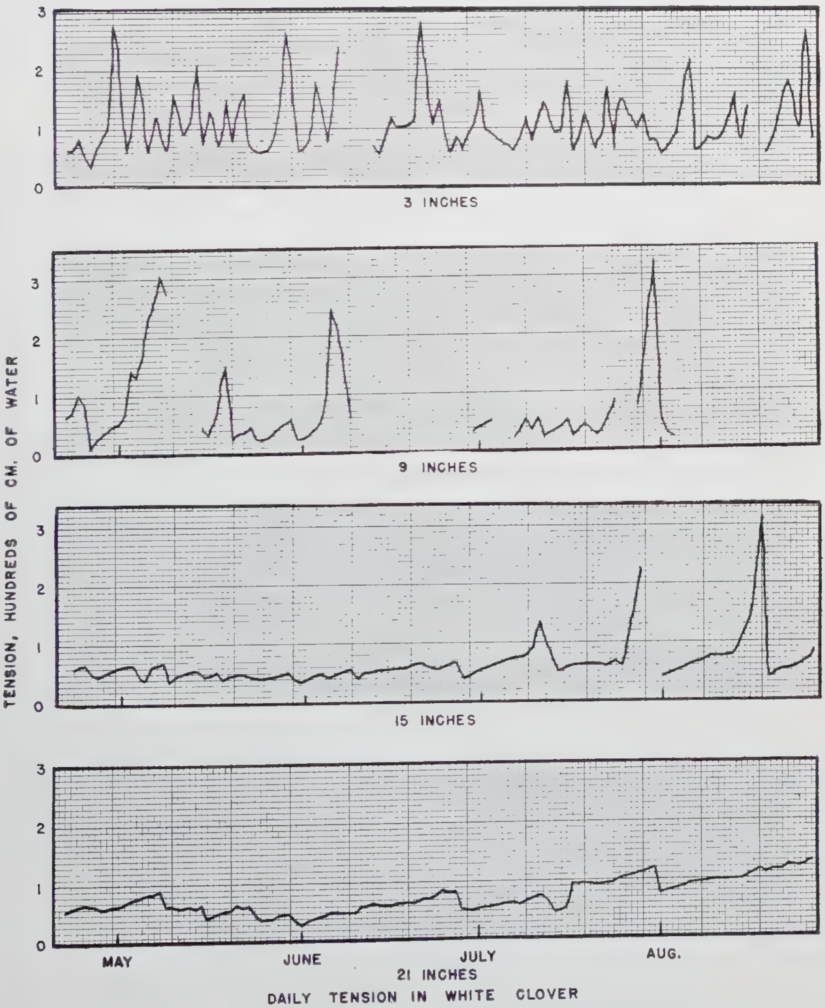


Figure 2.—Soil moisture tension in white clover, at the depths indicated, when the maximum tension schedule was 200 centimeters of water.

The four depths to which the soil was wetted at irrigation were 0-6, 0-12, 0-18 and 0-24. To determine when irrigation was needed, tensiometers were placed three inches above the lower level of each depth, or at 3, 9, 15 and 21 inches.

The 36 tensiometers used in this study were fabricated, in the shops of the Agricultural Engineering Department, according to the specifications of Richards.[1] One tensiometer was located in each main plot, a different

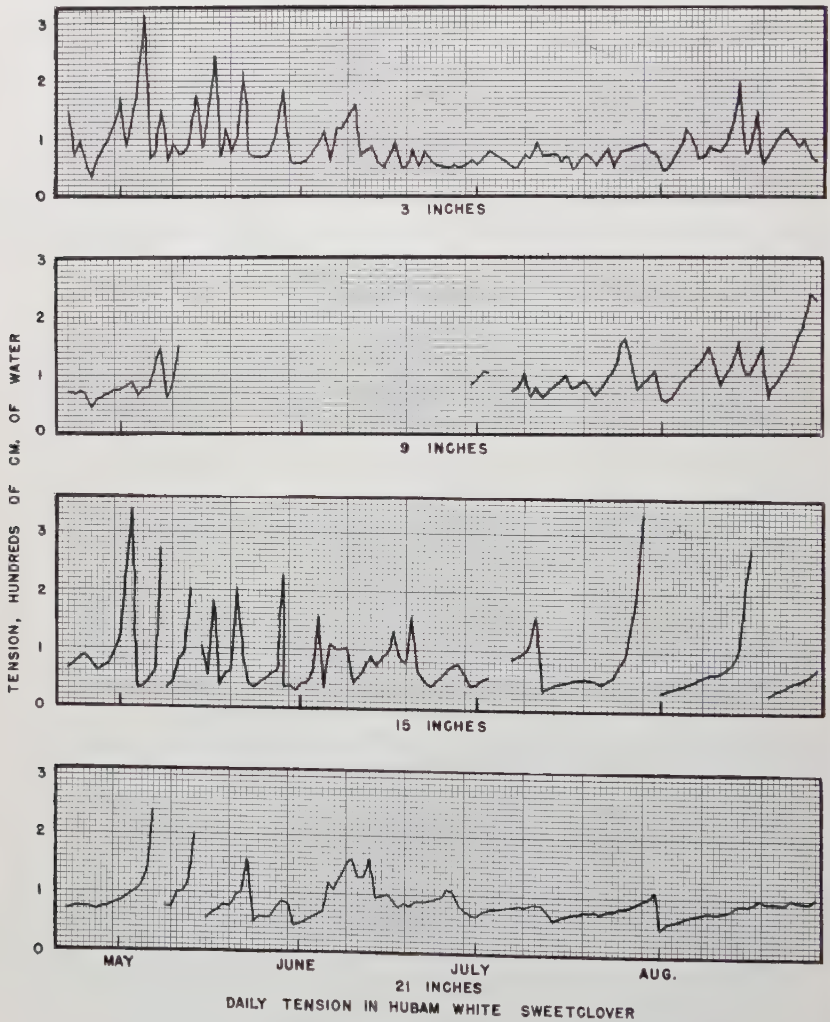


Figure 3.—Soil moisture tension in Hubam sweet clover at the depths indicated, when the maximum tension schedule was 200 centimeters of water.

[1] Richards, L. A. Soil Moisture Tensiometer Materials and Construction, Soil Science 53, pp. 241-248, 1942.

pasture species sub-plot being chosen in each of the four replications. The tensiometers were read at the same time each morning in order that the day-to-day comparisons would not be affected by the diurnal-temperature-induced fluctuations.

Irrigation treatments were begun on April 17, 1952, and concluded on August 27, a period of 132 days. The water was distributed over the plots through three-inch perforated, portable aluminum pipe. The system was calibrated by operating the pump at a pressure head of 20 psi and simultaneously measuring, by means of standard rain gauges, the rate of irrigation delivered through the system. Subsequent irrigations were controlled by operating at a pressure of 20 psi for the time interval computed for the inches of irrigation required.

Clippings for yield were taken with a plot mower removing a 1/2000 acre swath from the center of each sub-plot. These samples were dried at 130° F., weighed, and yields expressed in pounds of dry matter per acre. The Hubam was clipped only once (June 5), while the white clover was cut twice (May 6 and June 5). At about monthly intervals, Pangolagrass was clipped 3 times and Bahiagrass 4 times, the final harvest for both grasses being August 21.

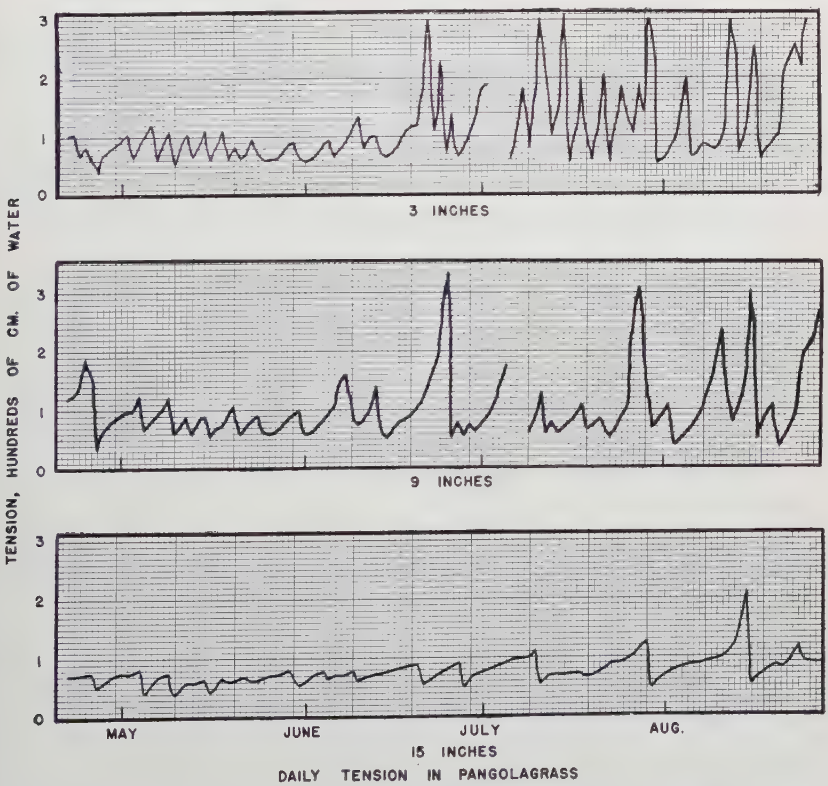


Figure 4.—Soil moisture tension in Pangolagrass at the depths indicated, when the maximum tension schedule was 200 centimeters of water.

RESULTS AND DISCUSSIONS

The 55-year mean rainfall for the 132-day irrigation period is 24.86 inches. However during this period in 1952, the amount was only 13.20 inches. The rainfall for the months of June, July and August was considerably below normal. The distribution of the irrigations required for the 200 cm tension at the various depths, along with rainfall for the same period, is shown in Figure 1. The 800 cm tension levels at respective depths required less frequent irrigations. A comparison of the number of irrigations and total amounts applied to the different treatments during the season are shown in Table 2.

The changes in soil moisture tension over the season as reflected by fluctuations in tensiometer readings are shown for the 200 cm tension range in Figs. 2, 3, 4 and 5. A rapid increase in tension is evidence that moisture was being removed at a relatively high rate from the soil zone in which the tensiometer was located. There was considerable variation in fluctuations between treatments and species. For white clover, the greatest fluctuation occurred in the 0-6 inch zone. At 12-18 and 18-24 inches, the fluctuations were extremely slight. White clover then was withdrawing water most rapidly from the 0-6 inch zone and almost none below 12 inches. Hubam differed by withdrawing moisture uniformly

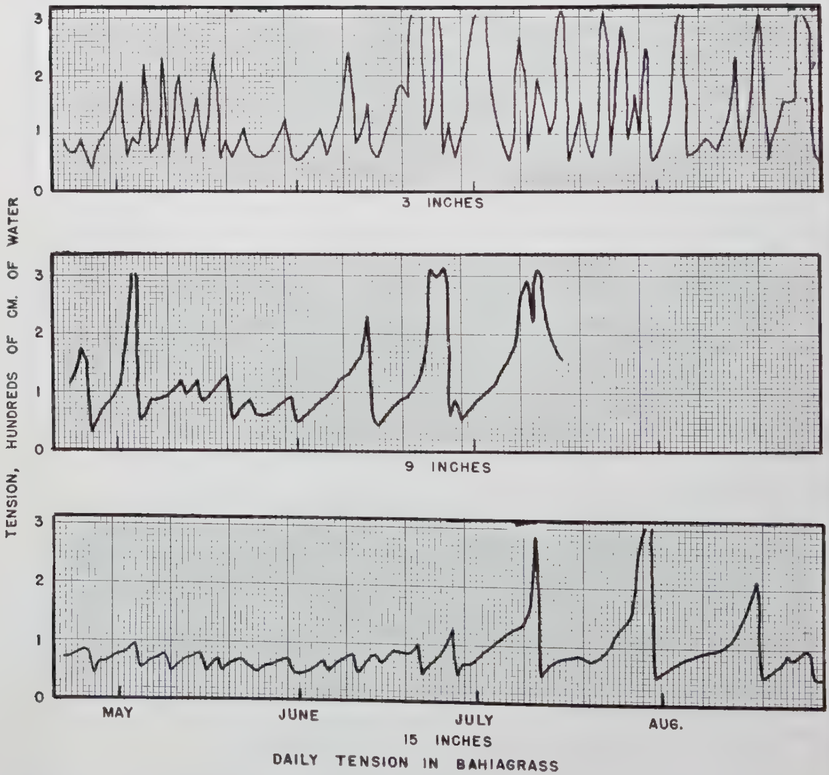


Figure 5.—Soil moisture tension in Argentine Bahiagrass, at the depths indicated, when the maximum tension schedule was 200 centimeters of water.

from the top 18 inches, and there was evidence of moisture utilization in the 18-24 inch zone. The clovers died after the second harvest, June 5, and the reduced tensiometer fluctuations indicate the absence of water withdrawal by the plants. Irrigation did not extend the growth period for the clovers. The more rapid encroachment by weeds in the white clover compared to Hubam is evidenced by the smaller amplitude of the tensiometer fluctuations in the hubam plots after June 5 (Figs. 2 and 3).

TABLE 2.—Number of Irrigations and Inches of Water Applied for the Various Treatments During the 1952 Season

Depth Soil Wetted	Number of Irrigations		Water Applied per Season	
	Tension Range 200 cm Water	Tension Range 800 cm Water	Tension Range 200 cm Water	Tension Range 800 cm Water
			Inches	Inches
0-6	20	5	4.40	2.00
0-12	12	7	6.00	5.74
0-18	12	2	8.40	2.46
0-24	4	0	4.08	0.00

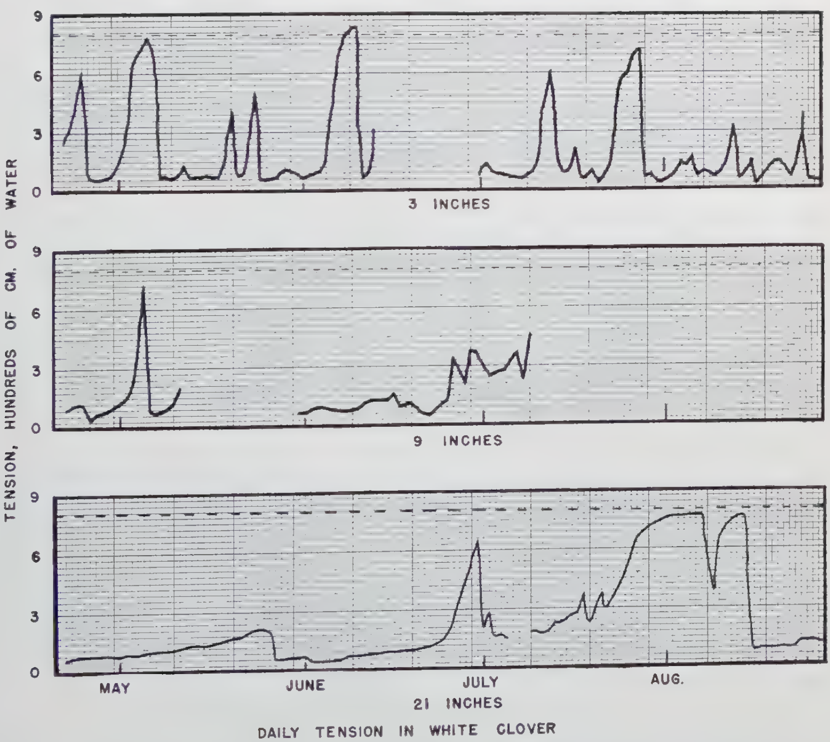


Figure 6.—Soil moisture tension in white clover, at the depths indicated, when the maximum tension schedule was 800 centimeters of water.

Both Bahiagrass and Pangolagrass withdrew water most rapidly from the 0-6 inch zone (Figs. 4 and 5). There was evidence that Bahiagrass withdrew somewhat more water from the 18-24 inch zone than did Pangolagrass; however, this utilization was small, compared to that from the 0-6 inch zone. Bahiagrass began growth earlier than did Pangolagrass, as indicated by the greater amplitude of tensiometer fluctuations for Bahiagrass in early May (Figs. 4 and 5).

With respect to zone of moisture withdrawal, the moisture fluctuations for the 800 cm tension range followed a similar pattern to that of the 200 cm tension treatments (Figs. 6, 7, 8 and 9). The fluctuation in tension was less frequent under the 800 cm tension treatment, while the amplitude was greater.

The relative total yields for the irrigation treatments compared to the non-irrigated treatment are shown in Fig. 10. The zero line for each species is the non-irrigated treatment yield which was 3040, 1350, 3685 and 3940 pounds dry matter per acre for Hubam, white clover, Bahiagrass and Pangolagrass respectively. An increase of 60 and 56 per cent on Bahiagrass and Pangolagrass respectively was required for statistical significance at the 5 per cent level as indicated by the dotted lines (Fig.

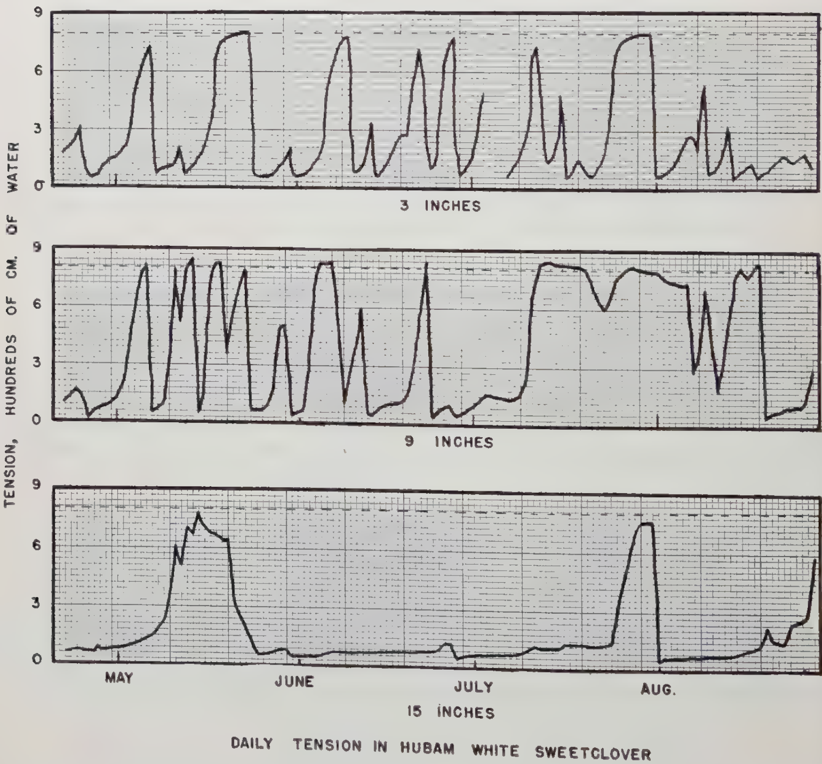


Figure 7.—Soil moisture tension in Hubam sweet clover, at the depths indicated, when the maximum tension schedule was 800 centimeters of water.

10). The differences between treatments for Hubam and white clover were not significant at the 5 per cent level. The high variability in yields was largely caused by non-uniformity of stands during the first season. However, there was a tendency for all species to give greater yields when irrigated at the high moisture range of 200 cm tension compared to the treatments delaying irrigation until 800 cm tension had been reached.

SUMMARY

A pasture irrigation experiment, involving four depths of wetting, two soil moisture ranges and four pasture species, was conducted near Gainesville.

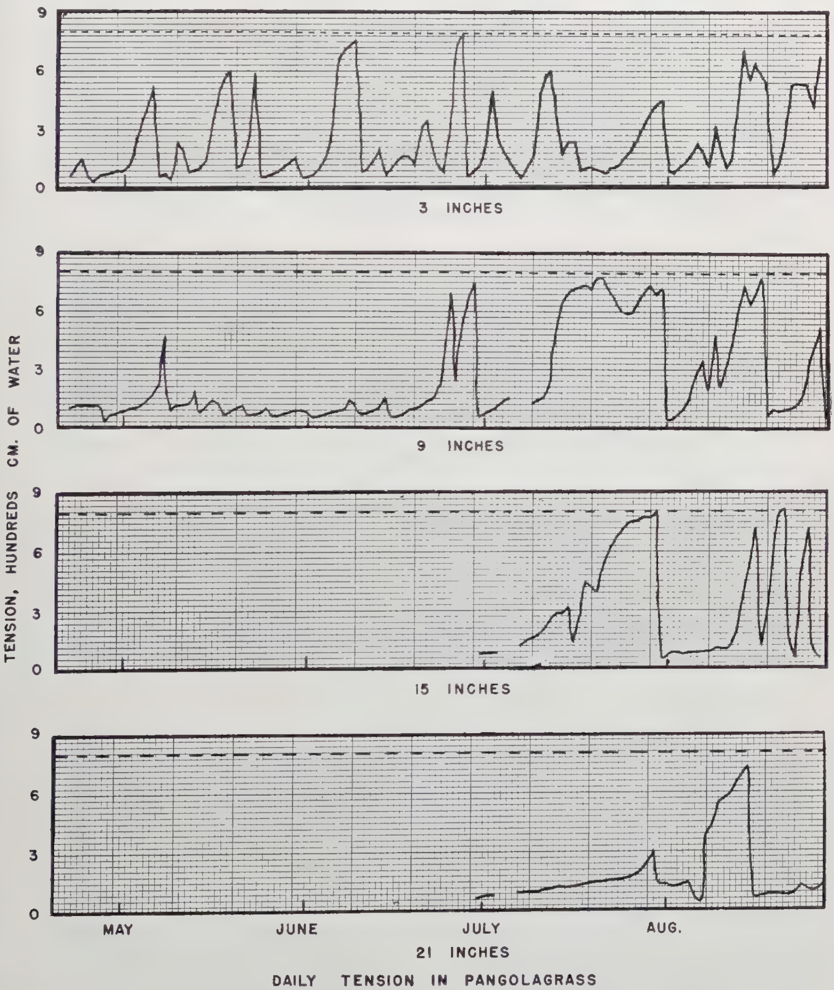


Figure 8.—Soil moisture tension in Pangola grass, at the depths indicated, when the maximum tension schedule was 800 centimeters of water.

During the summer of 1952, the zone of moisture withdrawal, as indicated by soil moisture tensiometers, varied with the species. White clover withdrew little moisture beyond a depth of twelve inches, while Hubam, Pangolagrass and Bahiagrass withdrew some moisture to a depth of twenty-four inches.

While the differences in yield were not statistically significant in all cases, definite trends were apparent. Most species gave a greater yield when irrigated at a tension of 200 cm than when irrigated at a tension of 800 cm. Controlling irrigation by tension measurement in the 18-24 inch zone resulted in yields only slightly greater than yields from the non-irrigation treatment. None of the irrigation treatments extended the growth period of the clovers.

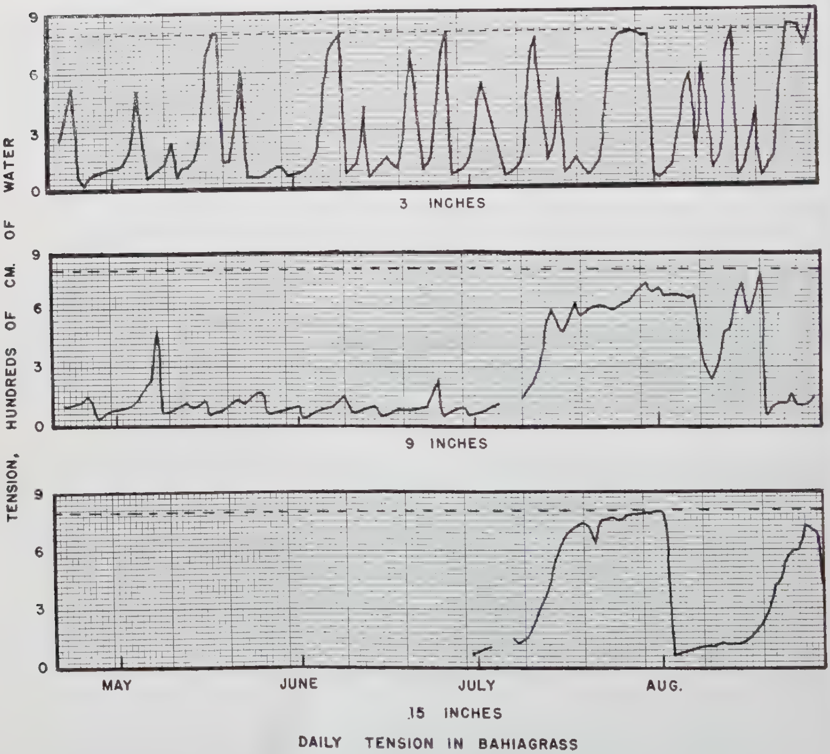
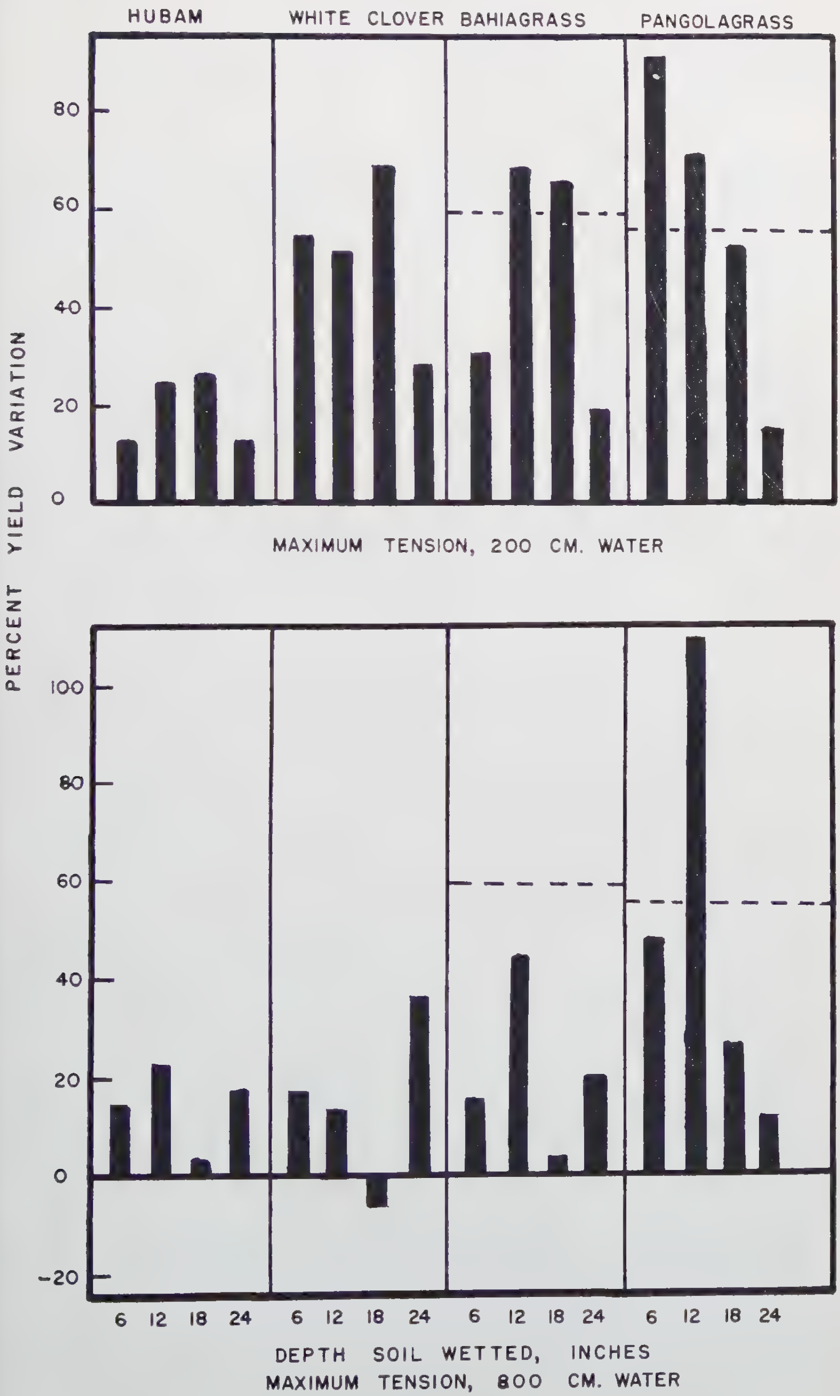


Figure 9.—Soil moisture tension in Argentine Bahiagrass, at the depths indicated, when the maximum tension schedule was 800 centimeters of water.

Figure 10.—Per cent variation in yield for the various treatments. The non-irrigated plot yield for each species is shown by the zero value on the ordinant.



PERCENT VARIATION IN YIELD OVER NON-IRRIGATED VS TREATMENT FOR THE FOUR SPECIES SHOWN

POTASSIUM REQUIREMENTS FOR PASTURES

Nathan Gammon, Jr., and William G. Blue*

Present average annual applications of potash to improved pastures in Florida generally range from 30 to 60 pounds per acre. Higher rates are used, but only in exceptional instances. Since a simple calculation shows that one ton of clover hay should contain about 50 pounds of potash, the deficiency of these low rates of potash fertilization becomes strikingly apparent.

In the sandy soils of Florida, no accumulation of available potash has been shown under pasture conditions, even with annual rates of potash application in excess of 100 pounds per acre. This may be attributed to the low exchange capacity of these soils and the eventual concentration in cattle urine of most of the potash in pasture forage. The potash is returned to the soil in localized areas and in concentrations in excess of the ability of the soil exchange complex to retain it; thus, the surplus is readily lost by leaching rains. The potash conservation picture as related to pastures seems dark: since under the present management system, accumulated evidence indicates that much of the fertilizer-potassium makes one trip through the plant and animal and then is leached away.

If fertilization with potash is primarily a one-cycle proposition as the data indicate, the potash fertilization program must emphasize two factors: time of application, and the fertilizer requirements of the crop. Both are of equal importance. Additional research is needed to increase the efficiency of potash utilization.

Potash should be supplied to pastures in several applications during the year, rather than in a single heavy application. When a single application is made, much of the potash may be lost in luxury consumption or leached before it can be utilized by the crop.

Two examples will illustrate these problems which are commonly encountered in clover pastures. One well fertilized clover pasture was grazed when the plants were quite small because the farmer's feed supply was low. These small plants contained a surplus of potash. Because this potash was removed by the early grazing, many of the plants developed potash deficiency symptoms and failed to produce the amount of feed that had been expected. Another clover pasture, adequately fertilized at planting time, was subjected to a very heavy rain about two weeks later when the clover plants were still small seedlings. The loss of potash by leaching was readily apparent; since a portion of the field which received extra potash a month later produced double the yield of the portion receiving no additional potash.

Examples of crop requirements and luxury consumption of potassium are shown in Table 1. The values reported for white clover and Pangola grass are quite accurate, since they represent observations from a number

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of experiments. The values for other grasses were obtained from a single experiment and are only approximate. Their relationships to each other are believed to be correct, however, since they were obtained under similar conditions.

TABLE 1.—POTASSIUM REQUIREMENTS FOR SOME PASTURE CROPS IN FLORIDA (Based on Herbage Four to Six Weeks After Clipping)

Plant	Minimum* K for Optimum Growth (% Oven Dry Herbage)	Maximum** K Found (% Oven Dry Herbage)
White Clover	2.0	5.0
Pangola	2.0	4.9
Weeping Love	.3	1.8
Common Bahia	.5	4.0
Pensacola Bahia	.6	3.0
Argentine Bahia	.9	3.4
Carpet	.75	3.4
Coastal Bermuda	1.0	3.1
Bermuda 99	.8	3.0

* Without reduction of dry weight production.
** Luxury consumption.

The high potash requirement of Pangola grass, together with its high capacity for luxury consumption, probably explains the difficulty sometimes experienced in getting a good clover stand in this grass. The reverse conditions probably explain the better stands of clover in Pensacola Bahia sods. If it were not for some of its undesirable features, weeping love grass might be the most desirable grass to grow with clover, from the point of view of competition for potash.

If these grasses grow at their maximum rate, Pangola requires about four times as much potash as common Bahia and seven times as much as weeping love to produce a ton of hay. This simple potash requirement relationship does not complete the picture however, since the quality of the feed may be different and properly fertilized Pangola may produce several times as much feed in the same unit of time. Data on these factors are very scarce, or completely lacking, but are needed in developing the pasture fertilization program.

Another difference in crop requirements is shown in Table 2. The feeding power of clover plants for potassium seems to be less than that of grasses. Data for white clover are shown because more examples were available, but limited data for other clovers were of the same magnitude. Data indicate that values for Pensacola Bahia seem to be representative of other common pasture grasses grown on sandy soils in Florida.

During the summer months in a grass-clover pasture, it is possible for normally growing grass to deplete the soil to plow depth of available potassium to the extent of 40 pounds per acre below the minimum required for normal clover growth. This shortage must be made up, and additional potash supplied, to obtain satisfactory clover growth and yields the following fall and winter. For this reason the use of fertilizers with higher potash content for fall fertilization of established grass-clover pastures is recommended. Mixtures such as 0-8-24 and 0-10-20 applied

at the rate of 500 pounds per acre are to be preferred over the currently popular analyses, 0-14-10 and 0-12-12, applied at the same rate.

TABLE 2.—SOIL LEVELS OF EXCHANGE POTASSIUM
(ppm. K)

Plant	Normal Growth	Reduced Growth	Deficiency Symptoms
White Clover	> 40	35-40	25-35
Pensacola Bahia	> 20	10-20	< 10

The Louisiana Agricultural Extension Service advises that a good grass-clover pasture will remove from the soil 110 pounds of potash per acre per year through grazing, and 60 pounds will be lost through leaching in the same period. This may mean that 170 pounds of potash per acre are required annually for maintenance of a productive pasture. Since applications of potash to Florida pastures are usually much less than 170 pounds per acre, it is probable that potash is a seriously limiting factor on the better soils used for grass-clover pastures in Florida.

SUMMARY

In considering the potash requirements for pastures on the sandy soils of Florida, attention was called to wide variations in the optimum potassium content of various pasture plants and to the differences between clovers and grasses in minimum soil requirements for optimum growth. The need for further data on potash requirements of pasture plants was emphasized. The data available indicate that current fertilizer practices in Florida do not supply sufficient potash for optimum growth of most pasture plants. Specific recommendations were made for use of fertilizer analyses containing more potash in the fall fertilization of grass-clover pasture.

SOME ASPECTS OF THE USE OF ANHYDROUS AMMONIA ON SANDY SOILS

William G. Blue and Charles F. Eno*

In the past 20 years anhydrous ammonia, as a source of nitrogen for agricultural crops, has advanced from the novelty stage to a widely used fertilizer material. In general, yield tests have shown it to be fully as good as other commonly used materials, such as $NaNO_3$, NH_4NO_3, and $(NH_4)_2SO_4$. Studies indicate that its rate of nitrification in most agricultural soils is sufficiently rapid to provide adequate nitrate for pasture and row crops.

Ammonia exists as a positively charged ion; as such, it has a retention advantage in open sandy soils over negatively charged nitrate ions. Its greater resistance to leaching should make possible larger, less frequent applications. Compared to the solid forms of nitrogen, it has the advantage of being better adapted to deeper placement. It is also the first product of nitrogen fixation by the Haber-Bosch process and contains a high concentration of nitrogen, about 82 per cent. Manufacturing and transportation costs are relatively low per unit of nitrogen. Anhydrous ammonia is usually, therefore, one of the cheapest sources of nitrogen.

There are two outstanding disadvantages: Expensive pressure equipment is needed to handle anhydrous ammonia; and present equipment for distribution is not well suited for use on fields containing roots or other obstructions.

Probably the major question involving the use of anhydrous ammonia on sandy soils is whether they will retain the quantity of ammonia applied. For economy, soils should retain quantities of nitrogen from anhydrous ammonia in excess of those normally used as maximum applications for other nitrogen sources. If sandy soils will hold quantities of this magnitude under conditions of field application, problems which arise should differ little from those with other nitrogen sources.

Jackson and Chang (2) and Martin and Chapman (3) have studied the possibilities of loss of ammonia nitrogen by volatilization. Laboratory procedures were used in both studies. They have pointed out that factors such as depth of placement of the ammonia and exhange capacity, pH, moisture content and temperature of the soil all influence ammonia retention. Jackson and Chang concluded that the gaseous loss of ammonia from soils of intermediate texture, moisture content and pH is not an important factor in the use of anhydrous ammonia as a fertilizer. Martin and Chapman obtained losses from volatilization on alkaline and poorly buffered acid soils.

EXPERIMENTAL PROCEDURES

In studying the possibility of loss of anhydrous ammonia by volatilization it was deemed desirable to determine the maximum amount which

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would be retained by sandy soils under conditions known to influence its retention. The apparatus used in making these determinations is shown in Figure 1. Soils were treated with ammonia and a 50 gram portion was weighed into a sintered glass filter tube. Pads of glass wool were placed at both ends of the soil column and the soil was slightly compacted to remove large air pockets. A $CaCl_2$ tube was attached to the soil tube and to this was attached a flask containing NH_4OH in varying concentrations depending upon the amount needed to saturate the soil. A small glass air-inlet tube was inserted into the NH_4OH flask and extended below the surface of the liquid. To the other side of the soil tube a flask containing a 4 per cent boric acid and indicator solution was attached which showed when ammonia had passed through the soil. This apparatus was attached to an aspirator pump.

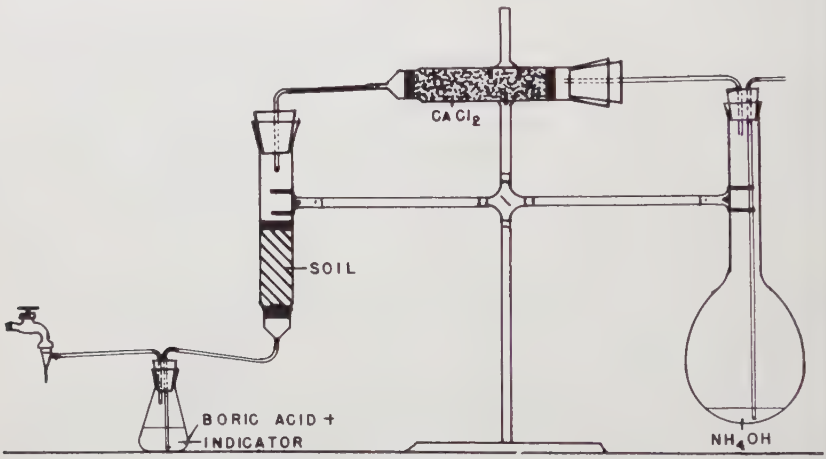

Figure 1.—Laboratory ammonia applicator for soils.

In operation, air was pulled through the NH_4OH causing ammonia to volatilize rapidly. The ammonia passed through the $CaCl_2$ tube where water and an insignificant amount of ammonia were absorbed. It then passed through the column of soil.

Ammonia was drawn through the soil column for two minutes in excess of the time necessary for it to move through the soil. This procedure was repeated for each sample. For convenience a two-hour time lapse occurred between each treatment. The tubes were then blown free of excess ammonia and concentrations were determined by leaching the soil with 400 ml. of 10 per cent NaCl and distilling the ammonia from the leachate.

Anhydrous ammonia was applied in the field using an applicator with knife-type injectors. The applicator was the "Nitro-Shooter"[1] manufactured by the John Blue Company, Huntsville, Alabama. The ammonia was applied approximately five inches deep and at 100 pounds of nitrogen per acre. The injector rows were spaced 16 inches apart. A single

[1] The authors wish to express their appreciation to the Southeastern Liquid Fertilizer Company for the use of this equipment.

rate of application was used because of limited facilities, and 100 pounds per acre was chosen because it was believed to be near the maximum single application rate for pastures.

All samples were taken to a depth of six inches with a sampling tube one inch in diameter. Samples of the injector row were taken with the center of the tube at the center of the row. Distribution of nitrogen from the injector was determined by taking successive samples one inch in diameter laterally from the injector row. A minimum of 10 plugs was composited. All samples were taken the day of application.

RESULTS

In studying losses of ammonia from conventional methods of application, it should be understood that the portions of the soil nearest the injector receive quantities of ammonia far in excess of the per acre rate of application. Table 1 shows the lateral movement of anhydrous ammonia to be relatively small. Anhydrous ammonia applied on sandy soils at 100 pounds per acre, in bands 16 inches apart, generally did not move laterally from the zone of application more than one and a half inches. Ammonia found at distances farther than one and one-half inches was very low. The result was a three-inch band of soil which contained the nitrogen that would, at the broadcast rate, have been present in a 16-inch band. The concentration of nitrogen in the three-inch band would be about five times as large as the 100-pounds per acre rate with broadcast application.

TABLE 1.—Distribution of Anhydrous Ammonia Nitrogen in Soil Expressed in Pounds per Acre

	Soils			
	I	II	III	IV
Control Area	8	12	9	8
Injector Row	805	240	269	270
1″ from Row	330	115	140	153
2″ from Row	15	18	10	23
3″ from Row	8	14	8	10

Soils air dried before analysis.

The concentration of ammonia in the immediate zone of placement, represented by a core of soil one inch in diameter, was, however, two to three times that in the succeeding one-inch band of soil. The 100-pounds per acre rate—which was not excessive as a broadcast application and could have been held by one-third milliequivalent of exchange capacity—was, as a result of being concentrated in narrow bands, 1000 or more pounds per acre in the bands. This quantity requires approximately three milliequivalents of exchange capacity. When exchange capacity, base saturation and other properties of the lighter, sandy soils are considered, their retentive capacity may be exceeded near the injector row.

In side-dressing row crops with anhydrous ammonia, the frequency of placement bands is much less than one every 16 inches. One placement band per row is common. With 38-inch rows, assuming somewhat the same distribution of nitrogen in the bands as with 16-inch spacings, the concentration of nitrogen at the zone of placement would be over two times that in the 16-inch bands. Thus, with an application rate of 100 pounds per acre, the concentration of nitrogen released at the point of application would be in excess of 2000 pounds per acre. This is an extremely high nitrogen concentration to be held by soils having relatively low exchange capacities.

Laboratory data in Table 2 show that most sandy soils used for agricultural purposes will hold ammonia nitrogen in quantities which approach or exceed 1000 pounds per acre. The ammonia nitrogen held as shown in Table 3 varied considerably depending on exchange capacity, pH and moisture content. The laboratory data indicate that the capacity of most soils for retention of ammonia is sufficiently large that the danger of ammonia loss, even with the high concentrations used, would be small.

TABLE 2.—MAXMUM AMOUNT OF AMMONIA NITROGEN HELD BY SOIL WITH VARIATIONS IN MOISTURE UNDER LABORATORY CONDITIONS

Soil Type	Exchange Capacity M.E./100 Grams	Initial pH	Per Cent Moisture	Lbs. NH_3N per Acre
Lakeland f.s.	2.0	6.43	0*	669
			1.7	780
			3.4	829
Rutlege f.s.	7.4	5.03	0	2,810
			9.2	3,925
			18.4	4,600
Arzell f s.	0.3	8.89	0	89
			2.4	131
Manatee f.s.l.	63 8	6.64	0	3,335
			25	12,450
Jonesville f.s.	2.5	6.00	0	865
			4	1,200
Red Bay f.s.l.	9.3	5.23	0	4,700
			8	6,420
			16	8,340
Blanton f.s.	3.2	5.67	0	1,487
			2	1,740
			3.9	2,080
Leon f s.	7.0	4.15	0	2,475
			3.4	2,945
			6.9	3,254
Leon f.s.	3.5	4.58	0	1,338
			2.6	1,788
			5.3	2,038
Leon f.s.	2.8	5.25	0	850
			2.1	1,164
			4.2	1,440

* Zero moisture indicates air-dry soil.

TABLE 3.—Pounds per Acre Ammonia Nitrogen Held by Soils with Variation in Per Cent Moisture and pH Under Laboratory Conditions

Ex. Capacity M.E./100 Gm.	Moisture Equivalent	Per Cent Moisture	pH				
Blanton Fine Sand							
			5.67	6.37	6.95	7.38	8.22
3.15	4.33	0*	1487	1220	1110	976	697
		1 96	1740	1465	1270	1115	896
		3.87	2080	1765	1630	1420	1003
Leon Fine Sand I							
			4.15	5.25	6.17	7.10	
6.99	7.04	0	2475	1780	1420	968	
		3.37	2945	2300	1926	1394	
		6 85	3254	2495	2175	1685	
Leon Fine Sand II							
			4.58	5.56	5.69	6.57	
3.53	5.63	0	1338	1177	919	581	
		2.60	1788	1613	1338	907	
		5.33	2038	1880	1598	1158	
Leon Fine Sand III							
			5.25	6 23	7.01	7.75	
2.78	4.45	0	850	748	543	386	
		2 09	1164	1030	853	653	
		4.20	1440	1275	1085	915	

* Zero moisture indicates air-dry soil.

Field applications of anhydrous ammonia show results, Table 4, which differ from the laboratory data. On the limited number of soils used, there was good agreement between concentrations of nitrogen found in the soil and soil properties known to affect ammonia retention. The two Arredondo soils, with relatively high exchange capacities and pH values near 5.5, held large concentrations of ammonia and losses during application were probably negligible. The concentration found in the Arredondo soil with a medium exchange capacity and pH of 7.15 was very low. The Lakeland soil with low exchange capacity but with a pH of 6.10, also held a relatively small quantity. The loss of nitrogen from the latter two soils ranged from 60 to 75 per cent.

A comparison of the amounts of ammonia held by the Lakeland fine sand in the laboratory with that found after field application, with moisture content approximately equal, showed that about twice as much could be held under laboratory conditions as was found in the field. This was the only instance in which laboratory and field data were secured for the same soil, but indirect comparisons of analyses of other soils indicate that the ratio between the maximum capacity for ammonia retention and the amount found under field conditions would be similar.

TABLE 4.—AMMONIA NITROGEN FOUND IN SOILS AFTER FIELD APPLICATIONS OF ANHYDROUS AMMONIA

Soil Type	Exchange Capacity M.E./100 Gm.	Initial pH	Per Cent Moisture	Location of Sample	Lbs./A. NH_3N
Arredondo l.f.s.	4.77	5.60	0*	Control Area	15
				Injector Row	732
Arredondo l.f.s.	2.77	7.10	0*	Control Area	12
				Injector Row	241
				1" from Row	114
Lakeland f.s.	2.03	6.10	1.02	Control Area	8
				Injector Row	386
				1" from Row	176
Arredondo l.f.s.	2.77	7.15	1.42	Control Area	9
				Injector Row	367
				1" from Row	150
Arredondo l.f.s.	4.70	5.45	5.94	Control Area	8
				Injector Row	1035
				1" from Row	378

* Air dried before analysis.
Ammonia applied approximately 5 inches deep at 100 pounds of nitrogen per acre.

Though field studies of ammonia retention with variations in moisture content have not yet been made, data presented in Table 5 suggest that loss of water from the soil by evaporation might be accompanied by ammonia volatilization. The conditions of evaporation are not normal since the soils were removed as samples before drying. It is interesting, however, that the percentage of loss of ammonia from soils taken from the zone of placement is relatively uniform. It is also of interest that in all cases the pH of the soil in the injector row after application of anhydrous ammonia was about 7.5. This occurred regardless of the initial soil pH.

TABLE 5.—LOSS OF AMMONIA NITROGEN FROM SOILS WHEN DRIED AFTER SAMPLING

Soil	Location of Sample	Per Cent Moisture	Lbs. per A. NH_3N		Per Cent Loss	pH of Air Dry Soil	
			Moist	Dry*		NH_3 Applied	No NH_3
Arredondo l.f.s.	Injector Row	4.6	238	172	27.8	7.42	7.00
	1" from Row	4.6	126	101	19.9	7.13	7.00
(Area 1)	Injector Row	1.4	367	269	26.7	7.75	7.00
(Area 1)	1" from Row	1.4	150	140	6.7	7.40	7.00
Arredondo l.f.s. (Area 2)	Injector Row	5.9	1035	805	22.2	7.37	5.40
	1" from Row	5.9	378	330	12.7	6.43	5.40
Lakeland f.s.	Injector Row	1.0	386	270	30.1	7.70	6.10
	1" from Row	1.0	176	153	13.1	7.40	6.10

* Air dried before analysis.

DISCUSSION

It should be pointed out that inaccuracies in the pump mechanism on the field applicator can cause some variation in the amount of ammonia applied. However, manufacturers of the pump used in this study have obtained an accuracy in field trials of 0.5 per cent. In no case is it likely that variations in the amount applied would be as large as were found for different soils, and in all instances there was good agreement between concentrations of ammonia found and soil properties which influence adsorption.

It therefore, seems quite conclusive that, even though many of the lighter sandy soils have the capacity for sorption of large quantities of anhydrous ammonia, properties of the material and present methods of application are such that efficient retention is not always possible. Data for concentrations of ammonia found when applied to row crops are not yet available. With wider spacing of the injectors and the resulting larger concentrations of ammonia, it is probable that the efficiency of retention would be even less than with the close spacing used for pastures.

Reasons for the gaseous loss of ammonia nitrogen from soils may be postulated. Limited movement from the zone of injection makes it necessary for a relatively small volume of soil to react with a large volume of gas. If immediate reaction does not take place, pressure will force the gas back into the air, since there is less resistance in air than in soil. A soil which has a capacity for sorption greatly in excess of that required would then react more quickly and would retain larger quantities of ammonia than one which has a marginal or submarginal capacity for retention. A high moisture content would also be beneficial, since ammonia is readily absorbed by water and the more dilute soil solution would permit greater replacement of adsorbed ions by the ammonia.

Loss of gaseous ammonia might be reduced by use of equipment which would provide for less lateral resistance. This has been accomplished by Mississippi workers who welded cultivator sweeps to the knife-type injectors (1). The sweeps apparently cause lateral shattering in heavier soils which allows the ammonia to come in contact with a greater volume of soil. The same benefit might be obtained from similar equipment on loose, sandy soils. It might also be possible to attach a plate, flush with the soil surface, to the knife-type injector. Upward movement of the gas would be retarded, giving more time for lateral movement and adsorption. Deeper placement also reduces loss by volatilization. The major difficulty of more complicated mechanical arrangements or deeper placement is that of use on land with roots or other obstructions such as is common in pasture areas.

Small applications of anhydrous ammonia will reduce losses during and after application. This, however, is a poor solution to the problem since the advantage of having a less readily leachable source of nitrogen is lost and the cost increases sharply as the number of applications necessary to apply a given amount is increased.

SUMMARY AND CONCLUSIONS

The possibility of gaseous loss of anhydrous ammonia when applied to sandy soils in the field was studied. A laboratory procedure was used to determine the maximum capacity for retention of ammonia by agricultural soils and to study the effects of variations in moisture and pH on retention. Analyses of soil samples for ammonia were made after field applications of anhydrous ammonia, to determine the distribution of nitrogen from the zone of injection. Analyses of different soils were also made to determine the concentration of nitrogen in the soil after a single, relatively large rate of application—100 pounds of ammonia nitrogen per acre.

It was found that the distance of movement of ammonia was relatively small. The capacity for retention of ammonia by most soils, as obtained by the laboratory procedure, was large. However, the application rate with current methods of distribution in no way indicates the concentration of anhydrous ammonia per unit of soil; the actual concentration in the soil near the injector row may be in excess of 10 times the per acre rate.

Both soil moisture content and pH significantly affected the capacity for ammonia retention by soils in the laboratory. The field retention of ammonia was found to be quite variable among soils and loss of ammonia was as great as 75 per cent. Low exchange capacity, high pH and low moisture content represent the poorest combination for retention.

It is believed that with present methods of application, losses of nitrogen from applications of anhydrous ammonia on the lighter, sandy soils do occur and in some cases may prevent its economical use.

BIBLIOGRAPHY

1. Andrews, W. B., J. A. Neely and F. E. Edwards. 1951. Anhydrous Ammonia as a Source of Nitrogen. Miss. State Agr. Exp. Sta. Bul. 482.
2. Jackson, M. L., and S. C. Chang. 1947. Anhydrous Ammonia Retention by Soils as Influenced by Depth of Application, Soil Texture, Moisture Content, pH Value and Tilth. Jour. Amer. Soc. Agron. 39: 623-633.
3. Martin, J. P., and H. D. Chapman. 1951. Volatilization of Ammonia from Surface-Fertilized Soils. Soil Science 61:25-34.

BANQUET AND BUSINESS MEETING

The Business Meeting, as usual, followed the regular program of the evening meeting on Friday, December 12th. The guest speaker for the occasion was Dr. Robert M. Salter, Chief, Soil Conservation Service, U. S. Department of Agriculture, Washington, D. C. He was preceded on the evening program by two papers, one by Drs. Ivan Stewart and C. D. Leonard and the other by Dr. Philip J. Westgate, both on the question of the use of certain of the chelated metals in relation to plant growth. All three papers are to be found published in full at the front of this volume.

BUSINESS MEETING

The reading of the minutes of the past meeting was dispensed with and the informal reports of the Secretary and the Editor were heard and approved, especially in the part where reference was made to the hope that the publication of all volumes of the Proceedings of the Society presently in arrears should be accomplished during the coming year.

A summarization of the total membership of the Society as published in the Appendix and elsewhere in this volume may be of particular interest. It is as follows:

	Annual	*Sustaining*	*Total*
Florida	514	68	582
United States—other than Florida	190	34	224
Caribbean area with C. A., S. A., and Mexico	80	6	86
Foreign—all other	17	5	22
Total	801	113	914
Honorary Life Members			11
GRAND TOTAL			925

REPORT OF THE TREASURER

STATEMENT OF RECEIPTS AND DISBURSEMENTS
YEAR ENDING DECEMBER 31, 1952

Cash on hand and in banks January 1, 1952		$10,212.20	
Receipts		3,433.48	
Total monies to be accounted for			$13,645.68
Disbursements			
Bank service charges	$ 1.00		
Travel	33.50		
Postage	95.00		
Proceedings publication	3,086.78		
Office assistance	988.90		
Expense annual meeting, including speaker travel	276.04		
Office supplies	77.57		
		4,558.79	
Cash on hand and in banks December 31, 1952		9,086.89	
Total monies accounted for			$13,645.68

REPORT OF THE NOMINATING COMMITTEE

There being no unusual changes in the official family of the Society during the year the only election necessary was to fill the position of vice-president made vacant by the automatic elevation of the incumbent in this office for the past year, Dr. Nathan Gammon, Jr., to the presidency.

The Nominating Committee appointed by President Wander at the close of the morning meeting consisted of Dr. W. T. Forsee, Jr., Chairman, Mr. T. W. Young and Mr. Glenn Lucas. In reporting for the committee Mr. Lucas presented the name of Dr. Ernest L. Spencer, Vice Director in Charge of Gulf Coast Experiment Station, Bradenton as the unanimous choice of the committee for Vice President and the chair then called for nominations from the floor. None were offered and in response to a motion and its second, with unanimous approval, the President, following the instructions of the motion, instructed the Secretary to cast a unanimous ballot for Dr. Spencer.

Following the reading of a Resolution of Sympathy in behalf of five fellow members who were taken by death during the year the meeting was adjourned.

MEETING OF THE EXECUTIVE COMMITTEE

Immediately following the adjournment of the General Business Meeting, President Gammon called a very brief meeting of the Executive Committee for the appointment of a Secretary-Treasurer and to discuss the program for the coming year. R. V. Allison was asked to continue in the above post.

With respect to the formulation of the next program the new Vice President was advised that this largely would be his responsibility, as in the past. It was decided that details could better be worked out at a later date when a special meeting of the Committee would be called for this purpose.

RESOLUTION OF SYMPATHY

Soil Science Society of Florida

WHEREAS, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come.

NOW, THEREFORE, BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

BOYD, GEORGE R.
U.S.D.A., Beltsville, Md.

HANEY, H. L.
West Palm Beach, Fla.

COACHMAN, WALTER F., JR.
Jacksonville, Fla.

KNAPP, J. V.
Tallahassee, Fla.

SPENCER, GEORGE S.
Miami, Florida

By the Resolutions Committee,
LUTHER JONES, Chairman.

I. W. WANDER

OFFICERS OF THE SOCIETY

1952

I. W. WANDER .... President

NATHAN GAMMON, JR. .... Vice President

W. T. FORSEE, JR. .... Member Executive Committee

R. V. ALLISON .... Secretary-Treasurer

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